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Growth Effects of Major Land Use Projects (Wastewater Facillities). Volume II. Summary, Predictive Equations and Worksheets

Abcor, Inc., Wilmington, MA. Walden Div.

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Volume II: Summary, Predictive Equations and Worksheets

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16. ABSTRACT

Growth Effects of Major Land Use Projects in a research program whose goal is to develop methodologies to predict the total air pollutant emissions resulting from the construction and operation of major land use projects. Emissions are quantified from the major project, from land use induced by the major project, from secondary activity occurring off-site (e.g., electrical generating stations), and from motor vehicle traffic associated with both the major project and its induced land uses.

This report documents the development of predictive equations for the induced land use from wastewater major projects. The predictive equations are included in an impact assessment procedure that estimates the total air pollutant emissions associated with induced development from a wastewater major project. This procedure is formalized in a set of easy-to-use worksheets, which serve as an operational tool for environmental engineers and planners.

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Volume II: Summary, Predictive Equations and Worksheets

by

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Urban Systems Research & Engineering, Inc. (USRE) of Cambridge, MA were subcontractors to Walden on this study, assisting in the definition of basic model concepts, infrastructure relationships and exogenous variables, and in the testing and refinement of the causal and predictive models. The cooperation of Dr. James F. Hudson, who guided the USRE technical effort, is deeply appreciated.

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*The first set of numbers refers to worksheets in English units, while the second set refers to metric units.

I. INTRODUCTION

A. STUDY OVERVIEW

Pursuant to 40 CFR 51.12(d)-(h), State Implementation Plans must contain provisions to prevent any national ambient air quality standards from being exceeded. These provisions are called Air Quality Maintenance Area (AQMA) plans, and estimating the air quality impact of major land use and urban development projects is a necessary part of AQMA planning [1-6]. In addition, the National Environmental Policy Act [7] and the Council on Environmental Quality (CEQ) "Guidelines on the Preparation of Environmental Impact Statements" [8] require the consideration of secondary impacts from major projects. CEQ states that:

> "Many federal actions, in particular those that involve the construction or licensing of infrastructure investments (e.g., highways, airports, sewer systems, water resource projects, etc.), stimulate or induce secondary effects in the form of associated investments and changed patterns of social and economic activities. Such secondary effects through their impacts on existing community facilities and activities, or through changes in natural conditions, may often be more substantial than the primary effects of the original action itself [8]."

This has been a particular concern for wastewater systems, since their primary impacts tend to be small, i.e., sewers and treatment plants generally improve water quality, but they may lead to significant negative secondary impacts. The probable large indirect impacts (redirecting growth and inducing development) of a new or expanded regional sewage treatment facility on ambient air quality, and the need for some procedure to ascertain what its impact will be, is recognized in the AQMA Guideline series ([1]:A-7ff, [4]:21ff). To date, EPA has not developed a model to estimate what the ambient impacts will be for use in AQMA planning. Thus, it was the purpose of this study to develop such a model.

This study is entitled the Growth Effects of Major Land Use Projects (GEMLUP-II), and it addresses the induced growth effects of wastewater major projects. Similar research on two other major project types, large residential developments and large industrial/office parks, has been performed previously and is reported on in the three volume set of GEMLUP-I final reports [9-11]. The secondary air quality impacts of wastewater projects are determined by the land use growth induced by such projects. That is, the air impacts are emissions from (1) residential complexes that appear at the end of and along new sewer lines, (2) other service-oriented land uses (commercial, industrial, office, government) that relate to residential development, and (3) motor vehicles used as transportation between development areas. Thus, the key to understanding secondary air quality impacts is to first understand the growth effects of a wastewater facility on land use in a region. The objectives of the study effort were: (1) to develop and test a path-analytic causal model that represents the induced land use ten years after construction of a wastewater major project, (2) to develop and validate a simplified predictive model of induced development, (3) to test and correct the GEMLUP-I VMT model [11], and (4) to develop worksheets that can be used to predict induced land use and associated air pollution emissions. For these purposes, data were collected from forty (40) case study wastewater projects nationwide.

The study project was divided into four major phases:

I. Definition of basic concepts and initial model specification,
II. Data collection,
III. Causal analysis of the land use model using path analysis,
IV. Development of predictive equations for the land use model and worksheet procedures.

Two separate technical reports are to be prepared. This is the second volume report and covers Phase IV of the study. The remainder of this chapter gives an outline of the general study approach, and a summary of results and conclusions for the entire study. Chapters II and Appendix A summarize the technical performance on Phase IV, including the development of the GEMLUP-II model work sheets. The technical performance on Phases I-III is summarized in the Volume I final report [12]. Appendix B gives a glossary of terms used in this report, and Appendix C summarizes definitions for the variables used in the GEMLUP-II model.

B. GENERAL APPROACH

The principal objectives of this study were to formulate a statistical methodology to predict air pollutant emissions from:

- Induced land development associated with the construction and operation of wastewater facilities in a community.*
- Motor vehicular traffic associated with the induced land development.

The ability to accurately predict the secondary development induced by major wastewater collection and treatment projects is dependent on understanding the complex interrelationships inherent in such a model. Thus, an important objective was to formulate and test a causal theory of induced development using path analysis. Additional objectives were to test and correct the motor vehicle traffic model developed as part of the previous GEMLUP-I study [11] for use in the air pollutant emissions projection procedure, and to integrate the predictive land use model, the traffic model, and land use based emission factors in a set of easy-to-use worksheets.

The approach to fulfilling these objectives involved the sequential execution of four separate project phases shown schematically in Figure 1-1 and summarized below.

In Phase I, our primary interest was to define the basic concepts on which this study is based. The first step in this process was to determine the modeling approach. Next, the infrastructure causal relationships of wastewater facilities in communities were studied and the knowledge used to define "induced development" in the model. The concepts of a "wastewater major project" and the "area of analysis" for induced development were also studied and defined. Knowing the important causal relationships enabled us to develop a list of model variables representative of the relevant factors involved (e.g., the major project, land use, regional growth).

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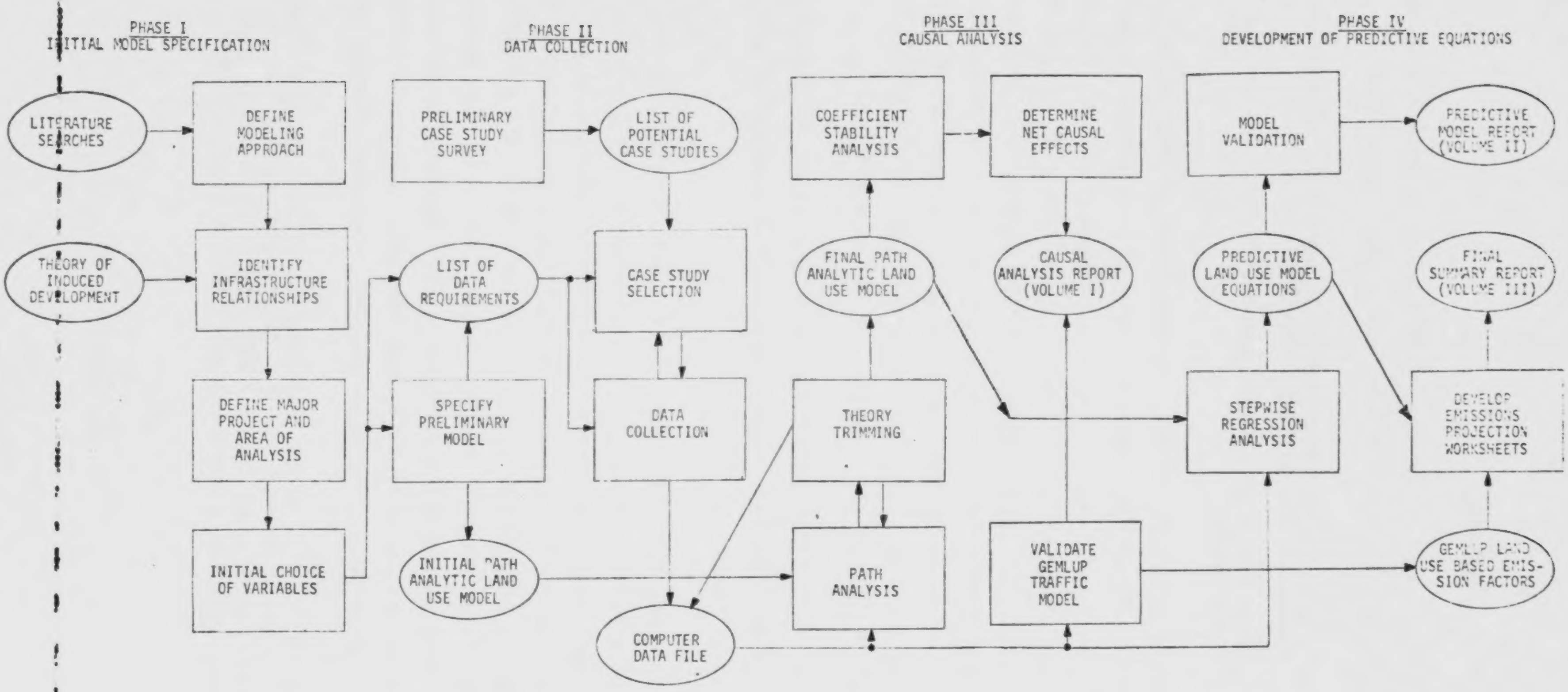
*The causal model for induced development produced by this study does not take into account the effects of mitigating measures. Variables measuring restrictions on on-site disposal and hookups to existing interceptor lines were included in the development of the model, however, see Volume I, Section II [12].


PHASE I
INITIAL MODEL SPECIFICATION
PHASE II
DATA COLLECTION
PHASE III
CAUSAL ANALYSIS
PHASE IV
DEVELOPMENT OF PREDICTIVE EQUATIONS
LITERATURE SEARCHES
DEFINE MODELING APPROACH
THEORY OF INDUCED DEVELOPMENT
IDENTIFY INFRASTRUCTURE RELATIONSHIPS
DEFINE MAJOR PROJECT AND AREA OF ANALYSIS
INITIAL CHOICE OF VARIABLES
PRELIMINARY CASE STUDY SURVEY
LIST OF POTENTIAL CASE STUDIES
LIST OF DATA REQUIREMENTS
CASE STUDY SELECTION
SPECIFY PRELIMINARY MODEL
DATA COLLECTION
INITIAL PATH ANALYTIC LAND USE MODEL
COMPUTER DATA FILE
COEFFICIENT STABILITY ANALYSIS
DETERMINE NET CAUSAL EFFECTS
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FINAL SUMMARY REPORT (VOLUME III)
STEPWISE REGRESSION ANALYSIS
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FIGURE 1-1

TECHNICAL APPROACH TO THE DEVELOPMENT OF A STATISTICAL MODEL FOR PREDICTING THE GROWTH EFFECTS OF MAJOR WASTEWATER PROJECTS

Finally, specific causal relationships between the variables were hypothesized and formalized in an initial causal model.

The principal objective of Phase II was to collect a sufficiently large, diverse, and thereby representative, cross-sectional data base on which to develop the model. Due to the critical importance of the quality of this data base and the large manpower effort required to collect such data, the first task required a careful selection of 40 case study wastewater major projects distributed on a nationwide basis, which had the potential, upon construction, to induce a significant quantity of land development in their communities and for which all the requisite data were available. To this end, a case study mail survey based upon the screening of over 15,000 federally funded wastewater collection and treatment projects nationwide was performed. Final selection of the 40 case study projects was made, a data collection training course was conducted for field personnel, followed by site visits to the case study areas to collect the required data.

The objectives of Phase III were to develop the final causal model and validate the GEMLUP-I VMT model [11]. The initial causal model was tested using the set of case study data and the statistical techniques of path analysis. This approach verified which of the hypothesized causal relationships were significant, trimmed those that were not, and determined model parameters for the final causal model. Tasks were also performed to trace the direct and indirect effects the model variables have on one another and to validate and correct the GEMLUP-I VMT model.

In Phase IV, predictive equations of induced land use associated with wastewater major projects were developed and validated. These predictive equations, the GEMLUP traffic model, and GEMLUP land use based emission factors [10] were then used as the basis for an emissions projection procedure. The procedure was developed in worksheet form to serve as a generalized analytical tool for use by planners and environmental engineers in predicting the induced land use and air pollutant impacts associated with major wastewater collection and treatment systems.

C. SUMMARY OF STUDY RESULTS AND CONCLUSIONS

1. Volume I - Model Specification and Causal Analysis [12]

A theoretical model of the Growth Effects of Major Land Use Projects has been developed. This model represents the total land use in the drainage basin of a wastewater collection and treatment system (the major project), ten years after its construction. The model represents the process of induced land use growth in the following 9 land use categories:

Residential
Commercial
Office-Professional
Manufacturing
Highways (Non-expressway)
Education
Recreation
Wholesale/Warehouse
Other

The assumption of a single basic causal structure for induced development, and the use of cross-sectional data from 40 diverse case study major projects throughout the United States, allowed a static approach to the testing of the theoretical model, using path analysis.

Path analysis is a set of statistical techniques useful in testing theories and studying the logical consequences of various hypotheses involving causal relations. It is not capable of deducing or generating causal relations, only testing them. The causal analysis of induced land use development in the current study involved the use of two basic statistical techniques: two-stage least squares and stepwise ordinary least squares (multiple regression). The first technique was required to produce consistent estimates of the path coefficients in a system of simultaneous equations involving feedback loops (or reciprocal causation) in the models. The second technique was used to solve the remaining recursive portions of the models. The dependent variables in these regression analyses represented the total land use in the previously noted 9 categories. Both linear and non-linear forms were tested and the linear form was found to produce the best fit. Specific statistical criteria were developed to identify model paths that were insignificant or redundant, and these criteria were used in an iterative process to trim unneeded and undesirable paths from the models. The trimming process eliminated almost half of the paths in the models as originally specified. The statistical problems of multicollinearity, suppressor variables and identification were eliminated through the approach used to trim the initial model.

The final models of land use development show that strong statistical relationships exist between the variables representing the 9 categories of total land use and the other model variables representing induced and non-induced land use growth processes. The results indicate that the final model explains more than half of the variance in the case study data with R^2 values ranging from 0.27 to 0.82 and averaging 0.54. The residuals of the final regressions do not exhibit any trends or patterns, indicating the remaining unexplained variance ($1-R^2$) is not due to poor specification of the model, but rather due to wide variance in the case study data (i.e., the problem of trying to develop one generalized model for a broad range of situations). An analysis of the stability of the model coefficients determined that, in general, the coefficient values have low variance (± 15%) and exhibit no extreme instabilities. An analysis of the net causal effects in the land use model indicates that reserve collection system capacity of a wastewater major project is a significant causal factor for induced land use growth, principally in the residential, manufacturing, education and highways categories. By contrast, treatment plant capacity was not found to be an important causal factor.

The GEMLUP-I VMT model [11] was validated using transportation data from 11 of the 40 case study major projects. Based on the validation results, it was concluded that revisions to both the default predictive equations for trip length and the default values for trip generation rates, were necessary. The revised VMT model was validated and found to have an average error (imprecision) of 23%, with no statistically significant bias.

2. Volume II - Predictive Equations and Worksheets

The development of predictive equations for land use development, separate from the model equations obtained in the causal analysis, was necessitated by the simultaneity of the causal relationships, i.e, the causal equations include independent variables whose values will not be known in the future. Therefore, it was necessary to develop predictive equations in which the endogenous variables appeared only as the dependent variables. Such an assumption defined a system of equations which was solved with ordinary least squares analysis.

Predictive equations were developed for the 9 land use categories used in the causal analysis. In addition, predictive equations were developed for disaggregating residential and commercial land use totals into 3 subcategories each. Logit analysis [14] was used with ordinary least squares regression to develop the disaggregation equations. The R^2 statistics averaged 0.67 and 0.76 for the land use and disaggregation equations, respectively. Thus, the predictive equations explained the majority of the variance in the dependent variables. Overall F statistics indicate all equations are significant at or below the 1 percent level. The average error associated with use of the predictive land use equations is ±63 percent. These errors are reasonable for a generalized tool, applicable nationwide, and are less than those introduced subsequently in the impact assessment procedure [16].

A model validation using the techniques of cross-validation and weight validity index [15] concluded that 8 of the 9 land use predictive equations are generalized enough to produce good predictions on an independent sample. Conflicting results were obtained for the OTHER equation, which may not be well generalized.

A coefficient stability analysis testing for worst case instabilities concluded that no significant instabilities occur in 7 of the 9 land use predictive equations. The exceptions, COMM and OTHER, contain instabilities which indicate that the true functional form of these equations changes with the magnitude of the data.

The predictive land use equations were included in an impact assessment procedure that estimates the total air pollutant emissions associated with the induced development from a wastewater major project. This impact assessment procedure was formalized in a set of easy-to-use worksheets, presented in Section II.D. These worksheets serve as an operational tool for environmental engineers or planners to assess the secondary air quality impacts associated with new or expanded wastewater facilities.

II. PHASE IV - DEVELOPMENT OF PREDICTIVE MODEL

The objective of the fourth and final phase of this study was to create and validate a predictive model to estimate the amount of induced land use (by category type) associated with major wastewater projects. These predictive equations were then incorporated along with the revised VMT model [12] and GEMLUP land use based emission factors [10] into an emissions projection procedure in worksheet form.

A. LAND USE PREDICTIVE EQUATIONS

1. Approach

The development of predictive equations for land use development, separate from the model equations obtained in the causal analysis (see Volume I [12]), was necessitated by the simultaneity of the causal relationships, i.e., causal equations include independent variables whose values will not be known in the future. Therefore, it was necessary to develop predictive equations in which the endogenous variables* appeared only as the dependent variables. Such an assumption defines a system of equations which can be solved with ordinary least squares analysis.

When predictive equations are developed using ordinary least squares for variables which are known to be effected by simultaneity, the individual regression coefficients are biased. However, the final prediction of the equation is an unbiased estimate of the dependent variable. Since these equations are to be used for predictive and not analytical purposes, the fact that the individual coefficients are biased estimates is not of great concern. It must be emphasized, therefore, that the regression coefficients obtained for the predictive equations should not be examined to judge the effects of independent variables on the dependent variable, nor should these coefficients be compared with those obtained in the causal analysis. Rather the appropriateness of a predictor can only be determined by examining its performance with regard to a set of objective statistical criteria.

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*See Appendix B for a definition of terms. See Appendix C for a definition of model variables.

In order to systematically decide which variables to include in the predictive equations, stepwise regression techniques were employed. The dependent variables in this stepwise regression analyses represented the 9 categories of total land use analyzed in the causal analysis and 6 percentage disaggregation categories for residential and commercial land use:

- RES = Residential
- COMM = Commercial
- OFFICE= Office-professional
- MANF = Manufacturing
- HIWAYS= Non-expressway highways
- EDUC = Education
- REC = Recreation
- WHOLE = Wholesale/warehousing
- OTHER = Hotel/Motel, culture, religion

Residential

- SFDET = Single family detached
- SFATT = Single family attached
- MF = Multiple family

Commercial

- PCOMM1= Buildings with <50,000 ft^2 GLA*
- PCOMM2= Buildings with 50-100,000 ft^2 GLA
- PCOMM3= Buildings with >100,000 ft^2 GLA

Although it would have been possible to develop predictive equations directly for the land use subcategories, it is advantageous to predict total, aggregate residential and commercial land use and then disaggregate the totals. There are two reasons for such an approach. First, results of the GEMLUP-I study indicate that average errors associated with aggregated predictive equations tend to be smaller. Second, by not directly incorporating the disaggregation of residential and commercial land uses into density classifications in the predictive equations, we allow the user of the predictive equations to enter in a land use density distribution applicable to some future time period of interest, different from that of 1960-1970. This second concern is motivated by the shift in density of new housing construction in the past few years away from single family detached developments, which predominated during the 1960s. Thus, we believe that this approach ensured a more generalized, predictive model.

---

*Gross Leasable Area

The next step was to decide which independent variables to include in the predictive equations. A maximum of 6 independent variables were included in each equation to keep the predictive model simple and easy-to-use, to avoid possible degrees of freedom problems, and to keep confidence intervals small. The set of potential independent variables included all exogenous and instrumental variables* from the initial causal model. The choice of independent variables was dictated by the stepwise regression analysis, i.e., at each step the analysis chose from the set of all independent variables the one which explained the most additional variance in the dependent variable. Since the analysis can produce several different predictive equation forms depending upon the independent variables included in the analysis, and their priority, a set of statistical criteria were developed for application to each variable before its final acceptance in the model equation. These criteria were the following:

- A test to ensure an independent variable was significant, e.g., a minimum F statistic value of 1.7, corresponding to the 10% significance level.**
- A test to ensure the choice of the model form which explains the greatest amount of variance in the dependent variable, viz. the requirement that the chosen final form have the highest adjusted R^2 value.
- A test to ensure the absence of multicollinearity, viz. $\beta < 1.0$.

The stepwise regression analysis was applied, as described above, using data from all 40 case studies and programs from the SPSS software package [13]. It was decided that it was preferable to use the full set of 40 samples in developing the equations since this would produce the most valid, generalized model. All variables were used in unstandardized form. The results were predictive, linear equations in both English and metric units, discussed in the next section, with full statistical output summarized in Appendix A.

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* See Appendix B for a definition of terms. See Appendix C for a definition of model variables, in both English and metric units.

** That is, there was at most a 10 percent chance of accepting a variable as significant in the regression when it actually was not.

2. Discussion of Results

a. Land Use Equations

The land use predictive equations obtained by applying the previously discussed objective criteria to the stepwise regression analyses are summarized below. Summary statistics for these equations are shown in Table 2-1a. R^2 values indicate the predictive equations are explaining the majority of variance in the dependent variables, i.e., the mean value for this statistic was 0.67. The overall F statistics indicate all of the predictive equations are significant at or below the one percent level. The coefficient of variation is defined as the ratio of the standard error of estimate of the regression to the mean value of the dependent variable. The mean of the coefficients of variation for the land use equations is 0.63, indicating that the average error encountered in the use of these predictive equations will be ±63 percent. These errors are reasonable for a generalized tool, applicable nationwide, and are less than those introduced subsequently in the impact assessment procedure [16].

The predictive equations shown below constitute a set of equations applicable to an area of analysis where a wastewater major project of a certain size range will be or already has been built. They do not constitute a general land use predictive model.

> A major project is defined as the construction or extension of interceptor or collector sewer lines in a community in the United States that affected an increase in absolute system collection capacity of 1.0 million gallons per day (MGD) or more. Based on the distribution of data used in developing the model, the increase in collection capacity should not exceed 100 MGD.
>
> The area of analysis is defined as the legal service area of the major project in the base year, and it must contain a significant amount of vacant, developable land. Based on the distribution of data used in developing the model, the size of the area of analysis should be 5,000 to 75,000 acres.

TABLE 2-1a

SUMMARY STATISTICS OF THE LAND USE PREDICTIVE EQUATIONS

Dependent Variable	Number of Predictors	R^2	R^2_a	Coefficient of Variation
RES	6	0.74	0.69	0.38
COMM	6	0.57	0.50	0.81
OFFICE	6	0.70	0.65	0.59
MANF	6	0.63	0.56	0.89
WHOLE	6	0.76	0.72	0.67
HIWAYS	5	0.52	0.45	0.53
EDUC	6	0.75	0.71	0.36
REC	6	0.65	0.58	0.59
OTHER	6	0.67	0.61	0.88

TABLE 2-1b

SUMMARY STATISTICS OF THE DISAGGREGATION EQUATIONS

Dependent Variable	Number of Predictors	R^2	R^2_a
RP1	6	0.82	0.76
RP2	5	0.84	0.80
CP1	5	0.73	0.69
CP2	5	0.65	0.60

The use of these equations should be limited to situations in which the major project and areas of analysis are in these size ranges. Also, any application of the predictive equations should be qualified by the error range indicated by the coefficients of variation shown in Table 2-1.

(1) English Units.

RES = - 8,692 VACANT + 5,347 LAND + 16.42 RECAP1 + 11.24 MANJOB - 18,804 STAY + 487.2 DRIVE + 13,466

COMM = 4,302 SERVED - 4,515 VACANT - 28.84 KIDS + 6,249 ACCESS - 17.04 JOBCHG - 2.626 RECAP1 + 5,376

OFFICE = 719.5 RRMILE + 33,478 OZONED + 36.70 PEAK + 0.3334 DUACRE - 1,791 IZONED + 572.0 POPDIF - 459.9

MANF = 2,591 RRMILE - 3,890 VACANT + 2.978 MANJOB + 85,923 OZONED + 234.7 VACOFF + 22.7 AIRPRT + 611.2

WHOLE = 166.5 DRIVE + 86.28 VACOFF + 3.340 OFFJOB + 6,043 EMPOP + 6,949 UNEMP - 0.1065 PERCAP -1,911

HIWAYS = 35.22 RRMILE + 22.98 LAND - 0.1167 GOVT + 0.5379 RECAP + 25.94 CROSS + 11.35

EDUC = -3,186 POOR + 723.0 SERVED + 437.5 LAND + 95.17 LIMITS - 405.2 PERCHG - 1.415 COST + 428.9

REC = 270.4 RRMILE + 2.631 CAPAC2 + 322.1 PERCHG + 0.9742 OFFJOB - 3,226 VACHSE - 557.8 IZONED + 59.52

OTHER = 1,134 RRMILE - 0.3020 PERCAP - 12,175 VACHSE + 649.0 PERCHG - 295.4 INTDEN + 403.8 RZONED + 3,087

(2) Metric Units. The predictive model equations in this section are reported in metric units. The conversion of units involved only the dimension of distance. The following conversion factors were used:

$\text{mile}^2 \rightarrow \text{km}^2$, multiply by 2.589
$1{,}000\ \text{ft}^2 \rightarrow \text{m}^2$, multiply by 92.90
$\text{acres} \rightarrow \text{m}^2$, multiply by 4,047
$\text{miles} \rightarrow \text{km}$, divide by 1.609
$\text{acre}^{-1} \rightarrow \text{m}^{-2}$, divide by 4,047
$\text{mile}^{-1} \rightarrow \text{km}^{-1}$, divide by 1.609

RES = -2.148 VACANT + 1.321 LAND + 0.0041 RECAP1 + 0.0072 MANJOB - 4.646 STAY + 0.3117 DRIVE + 3.327

COMM = 987.5 SERVED - 1,036 VACANT - 6.621 KIDS + 3,714 ACCESS - 10.13 JOBCHG - 0.6029 RECAP1 + 1,234

OFFICE = 102.7 RRMILE + 7,685 OZONED + 8.424 PEAK + 0.1981 DUACRE - 411.0 IZONED + 131.3 POPDIF - 105.6

MANF = 369.6 RRMILE - 893.0 VACANT + 1.770 MANJOB + 19,724 OZONED + 53.87 VACOFF + 3.239 AIRPRT + 140.3

WHOLE = 98.23 DRIVE + 19.80 VACOFF + 1.985 OFFJOB + 1,387 EMPOP + 1,595 UNEMP - 0.0244 PERCAP - 438.7

HIWAYS = 0.0087 RRMILE + 0.0091 LAND - 0.00005 GOVT + 0.0002 RECAP + 25.94 CROSS + 0.0045

EDUC = -731.3 POOR + 170.0 SERVED + 100.4 LAND + 21.85 LIMITS - 93.02 PERCHG - 0.3248 COST + 98.45

REC = 168.1 RRMILE + 2.631 CAPAC2 + 322.1 PERCHG + 2.522 OFFJOB - 3,226 VACHSE - 557.8 IZONED + 122.9

OTHER = 161.8 RRMILE - 0.0693 PERCAP - 2,795 VACHSE + 150.0 PERCHG - 67.81 INTDEN + 92.70 RZONED + 708.5

b. Disaggregation Equations

Predictive equations for disaggregating residential and commercial land uses into subcategories were developed using logit analysis [14]. This approach fits the percentage data (P) to a logistic S curve. The result is a non-linear structural equation that relates the range 0 to 1 with a set of independent variables $(X_1, X_2, \ldots . X_n)$, viz:

$$P = (1 + me^{(b_1x_1+b_2x_2+\ldots.+b_nx_n)})^{-1} \tag{1}$$

P is a general term for the previously defined percentage variables SFDET, SFATT, MF, PCOMM1, PCOMM2, and PCOMM3. This approach avoids two problems which would arise if linear, stepwise regression analysis was used, namely (1) the value for P would not be constrained between 0 and 1 (i.e., 0% and 100%), and (2) the sum of the percentages predicted for all subcategories of a given land use type would not sum to 1 (i.e., 100%).

To translate equation (1) to a form that can be solved with linear, stepwise regression, the following transformation was made:

$$\ln (P/1-P) = \ln(m) - b_1x_1 - b_2x_2 - \ldots - b_nx_n \qquad (2)$$

This is equivalent to:

$$Y = a_o + a_1x_1 + a_2x_2 + \ldots + a_nx_n \qquad (3)$$

where: $m = e^{a_o}$

$b_1 = -a_1$

$\vdots$

$b_n = -a_n$

To constrain the total of predicted subcategory percentages to 1.0, it was necessary to apply logit analysis in an iterative manner. First, the percent of single family detached and large commercial developments were predicted. Then the residual percentages were predicted. Thus,

Residential

% Single family detached = RP1* = SFDET
% Multiple family = RP2 (1-RP1), where RP2 = MF/(SFATT + MF)
% Single family attached = 1-RP2 -RP1

Commercial

% >100,000 ft^2 GLA** = CP1 = COMM3
% 50-100,000 ft^2 GLA = CP2 (1-CP1), where CP2 = PCOMM2/(PCOMM1+PCOMM2)
% <50,000 ft^2 GLA = 1-CP2 - CP1

The R^2 statistics for the logit analysis, shown in Table 4-1b, indicate excellent predictive ability for the disaggregation equations, with value ranging from 0.65 to 0.84, and averaging 0.76. The complete predictive equations for RP1, RP2, CP1, and CP2 are summarized below.

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* The statistical output listed in Appendix A refers to RY1 which is simply the transform of RP1 used to solve for the coefficient values, i.e., RY1 = (RP1/1-RP1). This applies to RP2, CP1 and CP2 in a similar manner.

** Gross Leasable Area.

(1) English Units.

$$\text{RP1} = (1 + 92.8\,\text{EXP}^{**}(-\,0.0137\,\text{KIDS} + 0.000918\,\text{CAPCHG} - 0.784\,\text{SERVED} - 22.7\,\text{OZONED} + 2.98\,\text{STAY} + 0.181\,\text{HOSCHG}))^{-1}$$

$$\text{RP2} = (1 + 1.24\,\text{EXP}(-\,4.38\,\text{HSECHG} + 5.48\,\text{POOR} + 34.1\,\text{OZONED} - 0.732\,\text{RRMILE} - 0.0365\,\text{PEAK}))^{-1}$$

$$\text{CP1} = (1 + 0.104\,\text{EXP}(0.215\,\text{VACOFF} - 0.507\,\text{LIMITS} + 0.0232\,\text{CAPAC2} - 0.0159\,\text{KIDS} + 0.0603\,\text{TLIMIT}))^{-1}$$

$$\text{CP2} = (1 + 0.585\,\text{EXP}(1.54\,\text{PHASE} + 0.00459\,\text{TRANS} + 0.0178\,\text{DISCBD} + 0.00417\,\text{GOVT} - 1.48\,\text{VACANT}))^{-1}$$

(2) Metric Units.

The disaggregation equations in metric units are identical to those for English units with two exceptions: (1) the coefficient for RRMILE in RP2 changes to -0.454, and (2) the coefficient for DISCBD in CP2 changes to 0.0111.

B. MODEL VALIDATION

The usefulness of any set of predictive equations depends upon their generality. Only if a regression equation is based upon a data sample which is representative of the general data population can it provide accurate predictions in different situations. In the current study, where a fairly small data sample (40) was available for developing predictive land use equations, the question of validity was important. The preferred test of an equation's validity is an external validation, viz., applying it on a test case basis to an independent sample of data (i.e., independent of the sample on which the coefficient values were based) and observing its predictive ability. In the current study a separate, independent sample was not available. Therefore, the analytical technique of cross-validation was used to simulate the existence of such a test sample. In addition, a more precise weight validity index was also computed.

1. Cross-Validation

Cross-validation provides a measure of the overall validity of the predictive equations. The procedure involved splitting the case study data sample of 40 into two random samples of 20 each. The first sample of 20 consisted of case numbers[*] 1,2,3,5,6,7,10,12,13,14,18,21,24,26,27,29,30, 32,38, and 40; the second sample of 20 consisted of the remaining case numbers. The coefficient values in the predictive equations were recomputed using the first data sample of 20. These coefficient values, specifying

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[*] See Table 3-3 in Volume I [12] for a definition of case study numbers.

[**] EXP is the exponential function (e). Thus, $\text{EXP}(x) = e^{x}$.

9 land use predictive equations, were used in conjunction with data from the second sample of 20 to predict the values of the dependent variables in the second sample. Statistical comparisons were then made between actual and predicted values for the dependent variables in the second sample.

The correlation coefficients (R) between actual and predicted values are shown in Table 2-2, and graphs of the actual versus fitted (predicted) values are summarized in Appendix D. In this application, the R statistic represents a coefficient of validity of the predictive ability of each equation. Values in Table 2-2 range from -0.04 to 0.68. All R values but one are statistically significant at the 2% level or better. The exception is the OTHER equation, where R is not significantly different from zero. These results can be interpreted that 8 of the 9 equations are generalized enough to produce good predictions using an independent sample. Only the OTHER equation may not be well generalized. The poor performance of this equation could, however, be attributed to non-homogeneties in the data samples caused by the small sample size.

2. Weight Validity Index

The weight validity index is a new statistical technique [15] which essentially performs a validation without the need for a separate independent sample or having to split the original sample, as in cross-validation. Since the entire data sample of 40 is used in the test, it gives more precise estimates of validity for the equations being tested.

The procedure involved first obtaining the R statistic for an equation estimated on the full sample of 40 (see Table 2-1a). Next, the quantity $\hat{\rho}$ is computed as:

$$\hat{\rho} = \left[1 - \frac{(N-4)(1-R^2)}{N-n-1}\left(1 + \frac{2(1-R^2)}{N-n-1}\right)\right]^{1/2}$$

where: N = sample size = 40
n = number of independent variables (see Table 2-1a)

Then the weight validity index $\hat{\rho}_c$ is estimated by:

$$\hat{\rho}_c = 2\,\hat{\rho} - R$$

TABLE 2-2

COEFFICIENTS OF VALIDITY BETWEEN ACTUAL AND PREDICTED LAND USE FROM THE CROSS-VALIDATION ANALYSIS

Dependent Variable	Coefficient of Validity (R)	Statistical Significance Level
RES	0.64	1%
COMM	0.56	1%
OFFICE	0.46	1%
MANF	0.39	2%
HIWAYS	0.42	1%
EDUC	0.68	1%
REC	0.68	1%
WHOLE	0.63	1%
OTHER	-0.04	--

The values for $\hat{\rho}_c$ are summarized in Table 2-3. To interpret the results the values of R and $\hat{\rho}_c$ are compared for a given equation. If there is a significant drop from R to $\hat{\rho}_c$, then the equations are not well generalized. In the current application, $\hat{\rho}_c$ is only 3-9% less than R. This small drop in value indicates that all the predictive equations can be used confidently on a new sample and that they are all well generalized for predictive applications.

C. COEFFICIENT STABILITY ANALYSIS

To test the stability of the coefficient values in the land use predictive equations, a technique was devised which is very sensitive to instabilities. The analysis simulated a "worst case" in terms of instabilities, and thus is more stringent than the jackknifing approach used in the causal analysis [12]. The procedure involved reestimating the model coefficients when excluding a cluster of 2 or 3 samples that had the greatest potential for instabilities. For each equation, the independent variables with the two largest β weights were identified and, together with the dependent variable, examined for skewness in their distributions. Where extreme values occurred, the case study number was noted. All such numbers were combined to see if 2 or 3 case studies dominated. These were then the data samples excluded from the stability analysis regressions (see Table 2-4). The percentage change in coefficient values and the standard error of the regression* were then computed. These values are listed in Table 2-4 as well. Note that the excluded values may or may not be associated with large residuals. In fact, many times a small residual on an extreme value indicates the extreme value has a significant impact on the regression line and thus more potential for instabilities. Because of this, residuals were ignored in choosing the case studies to exclude.

The results in Table 2-4 reveal significant changes in the model coefficient values. The range in percent change is 1% to 111%, with an average of 38% overall. However, since there is a mixture of both + and - signs in the percentages, there may be compensating effects, i.e., the final

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*On a common degrees of freedom basis.

TABLE 2-3

WEIGHT VALIDITY INDICES FOR THE LAND USE PREDICTIVE EQUATIONS

Dependent Variable	Weight Validity Index	Regression R Value*	Coefficient of Validity**
RES	0.83	0.86	0.64
COMM	0.69	0.75	0.56
OFFICE	0.79	0.84	0.46
MANF	0.74	0.79	0.39
WHOLE	0.84	0.87	0.42
HIWAYS	0.66	0.72	0.68
EDUC	0.83	0.87	0.68
REC	0.75	0.81	0.63
OTHER	0.77	0.82	-0.04

* From Table 2-1a.

**From Table 2-2.

TABLE 2-4

SUMMARY STATISTICS OF THE PREDICTIVE EQUATIONS COEFFICIENT STABILITY ANALYSIS

Dependent Variable	Case Studies Excluded	Percent Change in Standard Error of Regression	Independent Variables	Percent Change in Model Coefficient Values
RES	7,11,13	- 9.9%	VACANT	+ 9
			LAND	-11
			RECAP1	-14
			MANJOB	-47
			STAY	+61
			DRIVE	-73
COMM	18,35	-36%	SERVED	-60
			VACANT	+59
			KIDS	+83
			ACCESS	-86
			JOBCHG	*
			RECAP1	+81
OFFICE	3,18,35	-15%	RRMILE	-54
			OZONED	-55
			PEAK	-34
			DUACRE	-13
			IZONED	+72
			POPDIF	-20
MANF	18,35	-20%	RRMILE	-64
			VACANT	+37
			MANJOB	- 1
			OZONED	-46
			VACOFF	-55
			AIRPRT	-81

*Variable not significant in regression excluding skewed cases.

TABLE 2-4 (CONTINUED)

SUMMARY STATISTICS OF THE PREDICTIVE EQUATIONS
COEFFICIENT STABILITY ANALYSIS

Dependent Variable	Case Studies Excluded	Percent Change in Standard Error of Regression	Independent Variables	Percent Change in Model Coefficient Values
HIWAYS	6,13,18	- 2.9%	RRMILE	-81
			LAND	-20
			GOVT	+28
			RECAP	-16
			CROSS	-49
EDUC	3,13	- 3.3%	POOR	+ 7
			SERVED	- 4
			LAND	- 5
			LIMITS	- 1
			PERCHG	- 4
			COST	+111
REC	11,18,27	- 5.6%	RRMILE	-18
			CAPAC2	+15
			PERCHG	-54
			OFFJOB	-12
			VACHSF	+28
			IZONED	+35
WHOLE	7,14	- 9.5%	DRIVE	-25
			VACOFF	-13
			OFFJOB	-19
			EMPOP	-31
			UNEMP	-69
			PERCAP	+25

TABLE 2-4 (CONTINUED)

SUMMARY STATISTICS OF THE PREDICTIVE EQUATIONS
COEFFICIENT STABILITY ANALYSIS

Dependent Variable	Case Studies Excluded	Percent Change in Standard Error of Regression	Independent Variables	Percent Change in Model Coefficient Values
OTHER	12,18	-44%	RRMILE	-73
			PERCAP	-68
			VACHSE	-81
			PERCHG	-75
			INTDEN	-79
			RZONED	+40

predicted values may or may not be changing. The standard error of the regression is an indicator of the precision of the predicted values. Thus, changes in the standard error, when excluding certain samples, provide information about the stability of an equation. The percent changes in the standard error listed in Table 2-4 range from - 2.9% to -44%. Note that all values are negative, indicating that, as would be expected, the regression does a better job on a narrower range of data (i.e., that which excludes highly skewed samples.) For 7 of the 9 equations, the percent change under worst case conditions is $\leq$20%. This indicates that no significant instabilities occur in these equations. The other two equations, COMM and OTHER, have percent changes of 36% and 44%, respectively. This indicates in both cases that an equation different from the true predictive equation does significantly better on a narrower range of data. Thus, the excluded points are causing instabilities in the COMM and OTHER equations. What these worst case instabilities represent are the fact that the functional form of the land use relationships change with the magnitude of the data. Thus, a single generalized equation (i.e., that used in the GEMLUP-II model) cannot be as precise as one developed for only a portion of the range of data.

D. EMISSION PROJECTION WORKSHEETS

The predictive land use equations discussed in the last section, serve as the input to a two-part air quality assessment procedure outlined in Figure 2-1. First, the predictions of future land use in the area of analysis of a major project are translated into stationary source emissions (for all criteria pollutants) using a set of land use based emission factors [10]. Second, the revised VMT model [11,12] estimates vehicle miles traveled, and hence mobile source emissions, generated by transportation actively servicing the land use types. These two emission components are then summed to give the user the total air pollutant emissions associated with the induced development from a wastewater major project.

This impact assessment procedure has been formalized in a set of worksheets, presented in this section. These worksheets serve as an operational tool that can be easily used by environmental engineers or planners to assess the secondary air quality impacts associated with new or expanded wastewater facilities.

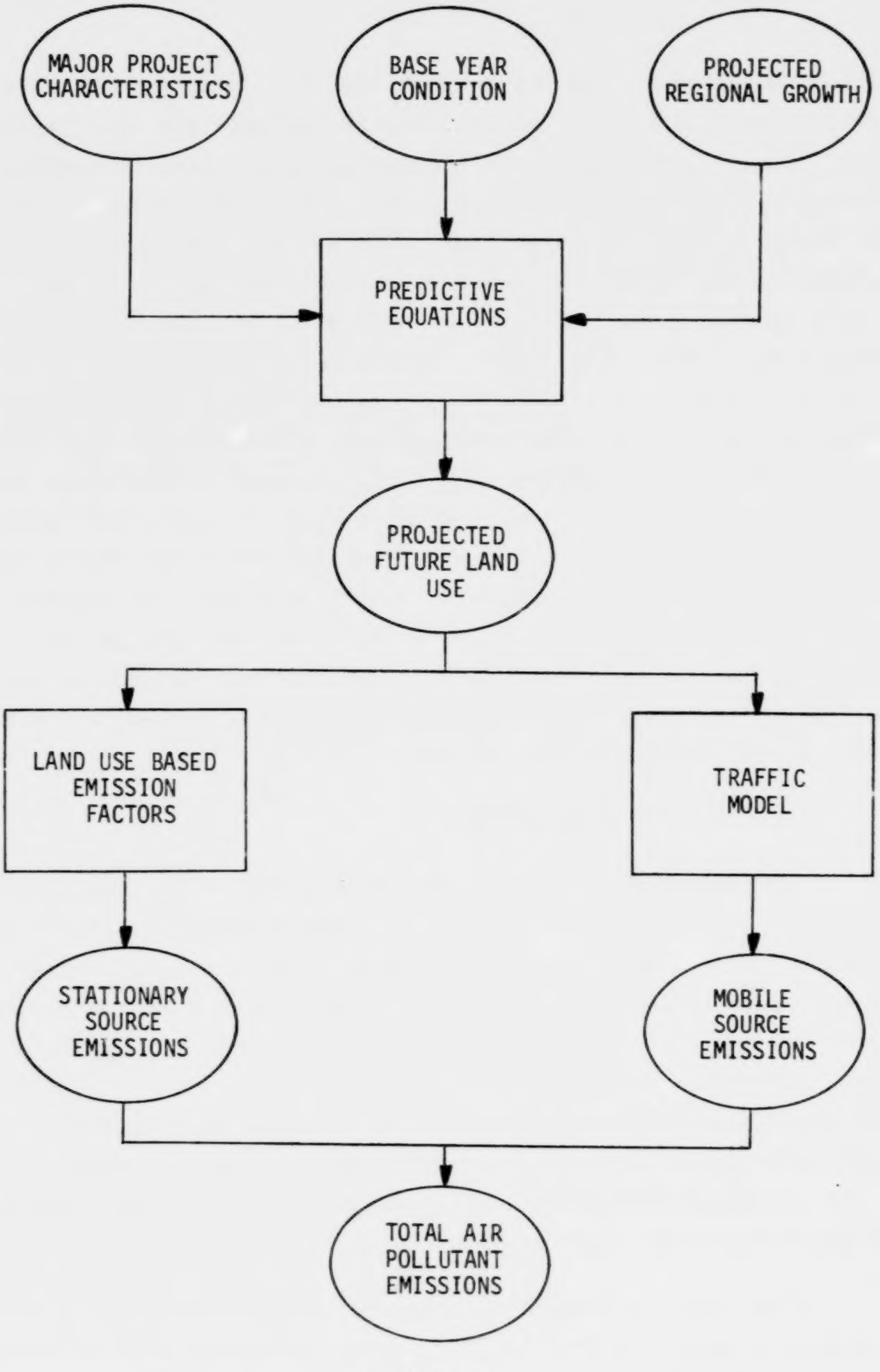
MAJOR PROJECT CHARACTERISTICS
BASE YEAR CONDITION
PROJECTED REGIONAL GROWTH
PREDICTIVE EQUATIONS
PROJECTED FUTURE LAND USE
LAND USE BASED EMISSION FACTORS
TRAFFIC MODEL
STATIONARY SOURCE EMISSIONS
MOBILE SOURCE EMISSIONS
TOTAL AIR POLLUTANT EMISSIONS

FIGURE 2-1

OVERVIEW OF THE LAND USE AND AIR QUALITY IMPACT ASSESSMENT PROCEDURE

1. Definitions

The predictive equations used in the worksheets constitute a set of equations applicable to an area of analysis where a wastewater major project of a certain size range will be, or already has been, built. They do not constitute a general land use model. They produce projections of total land use in the area of analysis ten years after the initiation of the major project. In this regard, the following definitions apply:

> A major project is defined as the construction or extension of interceptor or collector sewer lines in a community in the United States that affected an increase in absolute system collection capacity of between 1.0 and 100.0 million gallons per day.
>
> The area of analysis is defined as the legal service area of the major project in the base year, and it must contain a significant amount of vacant, developable land. It should be between 5,000 and 75,000 areas in area.
>
> The year t, or year of initiation, corresponds to the year the major project's new or expanded collection system first carried wastewater flows. If completion of the project was (or is to be) phased, it should be completed before the year t + 5.

The use of the worksheets should be limited to situations in which the major project and areas of analysis are in the size and time ranges noted above.

2. Input Data Requirements

The data required for application of the worksheets are summarized in Table 2-5. Here the variable names used in the worksheets are defined (in English units) and data sources are listed. The data required are generally available from regional planning agencies and the facility plans, and the total data collection task will require approximately two to three mandays of effort. Appendix C contains corresponding metric units for each model variable, as well as a cross-index relating worksheet variable names and predictive equation variable names. Photocopies of worksheet 1 (English units, starting on page 2-43) or 1M (metric units, starting on page 2-60) should be used to record actual values when collecting data. These are contained in Sections 4 and 5, respectively, along with all other worksheets.

TABLE 2-5

INPUT DATA REQUIREMENTS FOR IMPACT ASSESSMENT MODEL

Variable Name	Description (English Units[1])	Data Source
County Area	Area of county in square miles	County-City Data Book
Vacant Developable	Vacant developable acreage expected in area of analysis in year t[2]	Planning Agency
Vacant Undevelopable	Vacant undevelopable acreage expected in area of analysis in year t	Planning Agency
Zoned Residential	Acres of land expected to be zoned for residential use in area of analysis in year t	Planning Agency
Zoned Office	Acres of land expected to be zoned for office use in area of analysis in year t	Planning Agency
Zoned Industrial	Acres of land expected to be zoned for industrial use in area of analysis in year t	Planning Agency
Onsite Restrictions	Categorical variable to indicate the severity of existing or expected governmental restrictions on on-lot sewage disposal during the years t to t+10. Coded[3] as follows: 4 = on-lot disposal prohibited 3 = prohibited except on large lots 2 = permitted but percolation test required 1 = permitted but package plants prohibited 0 = no restrictions	Planning Agency or Local Government
Restriction Years	The number of years between year t and year t+10 that it is expected that any on-site sewage disposal restrictions will be in effect (i.e., a value of 0 to 10)	Planning Agency or Local Government
County Interchanges	Number of limited access interchanges expected in county in year t+5	Planning Agency
Limited Access	Number of limited access interchanges expected in the area of analysis in year t+5	Planning Agency

---

[1] See Table C-3 in Appendix C for corresponding metric units.

[2] t is the year of major project initiation.

[3] When restrictions are a mix of the five codes given, use the most restrictive condition (i.e., the highest value).

TABLE 2-5 (CONTINUED)

INPUT DATA REQUIREMENTS FOR IMPACT ASSESSMENT

Variable Name	Description (English Units)	Data Source
Transit Stops	Number of transit stops (bus and commuter rail) expected in area of analysis in year t	Planning Agency
County Growth	Percent[1] change in county population projected for the years t to t+10	Planning Agency
Future Population	Projected SMSA[2] population in year t+10	Planning Agency or BEA Projections [28]
Population Growth	Percent[1] change in SMSA[2] population projected between years t and t+10	Planning Agency or OBERS
Office Vacancy	Percent[3] of office buildings in area of analysis in year t that are expected to be vacant	Planning Agency or Realtor
Future Houses	Projected housing units in SMSA[2] in year t+10	Planning Agency or OBERS
Median Price	Projected median price of 1 acre of vacant residential land ($) in area of analysis in year t	Planning Agency or Realtor
Future Income	Projected median family income in SMSA[2] in year t+10	Planning Agency or OBERS
Future Employment	Projected SMSA[2] employment in year t+10	Planning Agency or OBERS Projections [18]
Future Medicals	Projected hospital employment in SMSA[2] in year t+10	Planning Agency
CBD Distance	Distance in miles[4] from centroid of area of analysis to centroid of nearest central business district in year t	Highway Road Map
Airport Distance	Miles from centroid of area of analysis to centroid of nearest commercial airport in year t	Highway Road Map
Track	Miles of railroad track in area of analysis in year t	USGS Topographical Map

[1] A value of 10% is coded as 0.1.

[2] If the area of analysis is not in an SMSA, use county data. In these instances two different variables may end up with the same value.

[3] A value of 10% is coded as 10.

[4] Air miles, not road miles. Central business district used is that in the nearest city with a population of 100,000 or more.

TABLE 2-5 (CONTINUED)

INPUT DATA REQUIREMENTS FOR IMPACT ASSESSMENT MODEL

Variable Name	Description (English Units)	Data Source
Area of Analysis	Area of analysis in acres	Facility Plan or Water Resources Plan
Sewered Land	Acres of land within 5,000 ft of the major project interceptor sewer in the area of analysis in year t	Facility Plan
Interceptors	Running length of interceptor sewer lines in miles going through relatively undeveloped land[1] in area of analysis in year t	Facility Plan
Collection Capacity	Total hydraulic design capacity of wastewater major project collection system in million gallons per day (mgd) in year t[2]	Facility Plan
Peak Flow	Anticipated peak flow in the wastewater major project collection system in mgd in year t	Facility Plan
Treatment Capacity	Total hydraulic design capacity of the major project wastewater treatment plant in mgd in year t	Facility Plan
Population Served	Population served by the major project facility in year t	Facility Plan
Project Cost	Total major project construction cost in thousands of $	Facility Plan
Federal Funds	Federally funded share of major project cost in thousands of $	Facility Plan
Phasing	Categorical variable to indicate whether the completion of the collection network will be phased over several years 1 = phasing will occur 0 = no phasing	Facility Plan
SMSA Area	Area of SMSA[3] in square miles	County-City Data Bk.

---

*See Appendix E for directions on how to gather these data.

[1] Less than one dwelling unit per acre.

[2] Year t or up to 5 years after year t if it is a phased project. Note this model should not be applied to major projects which are not completed by year t+5 (see Definitons on page 2-19).

[3] If the area of analysis is not in an SMSA, use county data. In these instances, two different variables may end up with the same value.

TABLE 2-5 (CONTINUED)

INPUT DATA REQUIREMENTS FOR IMPACT ASSESSMENT MODEL*

Variable Name	Description (English Units)	Data Source
Tract Area	Area of census tracts[1] in sq. miles	Census Tracts Map
Dwelling Units	Census tract housing units in 100s in year t (round off to nearest 100 units)	U.S. Census
Current Houses	Total housing units in SMSA[2] in year t	U.S. Census
School Kids	Population 0-14 years of age in census tracts in year t	U.S. Census
Vacant Houses	Percent[3] vacant available dwelling units in	U.S. Census
Nonmobility	Percent[3] of families in year t who were in the same house in year (t-5)	U.S. Census
Median Income	Median income of familes ($) in county[4] in year t	County-City Data Book
Current Income	Median family income ($) in SMSA[2] in year t	U.S. Census or OBERS
Poverty	Percent[3] of total families with income below the poverty level in	U.S. Census
Index One	Consumer Price Index[5] for the year t	(See footnote 5)
Index Two	Consumer Price Index[5] for the year of federal funding	(See footnote 5)
Government	Total county expenditures in millions of $ in year t	County Government
Current Employment	Total SMSA[2] employment in year t	U.S. Census or OBERS
Unemployment	Percent[3] unemployment in	U.S. Census

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*See Appendix E for directions on how to gather these data.

[1] Census tracts which most closely approximate the area of analysis. If area is untracted, use data for the municipality. This applies to all tracted census variables.

[2] If the area of analysis is not in an SMSA, use county data. In these instances, two different variables may end up with the same value.

[3] A value of 10% is coded as 0.1.

[4] County containing most of the area of analysis.

[5] Use U.S. Department of Labor statistics for the nearest major city, based on 1947-49 average prices being = 100.0. If t or the year of federal funding are not the current year, use consumer price index data for the current year, adjusted by the expected annual inflation rate.

TABLE 2-5 (CONTINUED)

INPUT DATA REQUIREMENTS FOR IMPACT ASSESSMENT MODEL*

Variable Name	Description (English Units)	Data Source
Office Workers	Office employment in census tracts in year t	U.S. Census
Manufacturing Workers	Manufacturing employment in census tracts in year t	U.S. Census
Current Medicals	Hospital Employment in SMSA[1] in year t	U.S. Census or OBERS
Drivers	100s of workers who drive to work in year t in the county (round off to nearest 100 workers)	U.S. Census

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*See Appendix E for directions on how to gather these data.

[1] If the area of analysis is not in an SMSA, use county data. In these instances, two different variables may end up with the same value.

3. Instructions

First, decide whether you will be using English or metric units, and then photocopy a set of the appropriate set of worksheets. Next, collect all the required data (as described in the previous section), enter the values on Worksheet 1*, perform the indicated operations, and record the answers in the boxes labeled "Inputs to Worksheets." Finally, fill in the photocopies of Worksheets 2 through 13 using the instructions below.

a. Projection of Future Land Use

Worksheet 2 computes the values of the 9 land use variables. Fill in all the blanks on the right-hand side of the equations with the appropriate data from Worksheet 1. Perform the arithmetic operations and record the results in the blanks on the left-hand side of the equations.

Worksheet 3 computes total land use in the area of analysis. First, copy the land use projection data from Worksheet 2 boxes into column (1). Next, enter the projected percentages for disaggregation of residential and commercial land use in column (2). These values must be between 0.0 and 1.0, and the three percentages for residential and commercial uses must each sum to 1.0. The percentages should take account of local factors which will affect the density of development in the area of analysis. In the absence of local data, default values can be estimated using the equations in Worksheet 4 (the input data for Worksheet 4 all come from boxes in Worksheet 1). Next, divide the Area of Analysis (first box on Worksheet 1) by 10,000 and enter the value in column (3). Final land use projections (4) are now obtained by taking the product of columns (1), (2) and (3).

Worksheet 5 is another optional worksheet which can be used to estimate 90% confidence intervals for any one of the land use projections in Worksheet 3. First, enter the name of the land use category at the top of the worksheet. Next, under Predictor Variable Name, list the name of the 5 or 6 predictors from the appropriate equation in Worksheet 2. Next, enter the values for these predictors from Worksheet 2 in the spaces to the right of the names. If only 5 predictors are used, enter 0.0 on line 6. The co-variance data required is summarized in the statistical output in Appendix A, and Page A-1 gives you an index to where to look for these data. In order to read the statistical output, it is first necessary to translate predictor names into the acronyms used in the model, and Table C-3 provides a cross-index to do this. Record the covariance data on Worksheet 5 and perform the indicated arithmetic operations. An example of this procedure is shown on page 2-83 and discussed below. In the example on Page 2-83, a confidence interval is being estimated for the "Single Family Detached" land use category so this is recorded at the top of the Worksheet. Since this category evolved from the "Residential" equation on Worksheet 2 (Page 2-80), we list the names and values of the 6 predictors from the "Residential" equation in the spaces at the top of Worksheet 5. Then we go to Table C-3 (pp. C-16 thru C-18), find the acronyms for the predictor names, and record these at the top of Worksheet 5 as well. Next, we go to Page A-1 and in the index find that page A-2 contains the covariance data we need. At the bottom of Page A-2 is a matrix from which we extract values corresponding to a pair of variables. For example, the first covariance value needed in Worksheet 5 is for "① x ①", that is the covariance of variable ① (which is VACANT) with itself. From the matrix we find "0.716E+07" at the intersection of VACANT and VACANT which is then copied onto Worksheet 5, and so forth.

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*The discussion in this section will use worksheets for English units. The instructions for metric worksheets are identical, except each worksheet number has a suffix M, i.e., 1 becomes 1M, etc.

b. Calculation of Motor Vehicle Traffic

The worksheets presented in this and following sections are based on the revised GEMLUP-I traffic model [11,12]. Due to its simplistic approach, the appropriateness of transportation parameters used in the model is extremely important. Thus, although default values are provided for most parameters, it is considered desirable to use local sources of transportation data whenever possible.

Worksheet 6 is used to compute total vehicle trips in the area of analysis for two trip purposes - Work and Other. First, compute a value for the Effective Radius by completing the calculation shown at the top of Worksheet 6. This definition uses a value based on a circle with an area equivalent to that of the actual area of analysis. That is,

$$\text{Effective Radius} = ((\text{Area of Analysis}/640)/\pi)^{1/2}$$

Next, enter the values for Projected Land Use in column (1). Enter values for Work and Other trip generation rates in columns (2) and (4), respectively. If local data are not available, default values are given in Table 2-6. Compute Work trips by multiplying columns (1) and (2); compute Other trips by multiplying columns (1) and (4). Compute Residential Work Trips and Residential Other Trips by summing the first three rows of columns (3) and (5), respectively. Compute total Work Trips and Total Other Trips by summing all items in columns (3) and (5).

Worksheet 7 is used to compute vehicle miles traveled (VMT) in the Area of Analysis and in the "Impact Area". VMT in the Impact Area are defined to include both the VMT within the Area of Analysis, as well as VMT outside the Area of Analysis but occurring because of the presence of the major project and its induced land uses. First, enter values for the Work and Other trip lengths. If local data are not available, use the following default equations:

$$\text{Work Trip Length} = 0.00447 * p^{0.20} * S_1^{1.49} \qquad \text{(in miles*)}$$

$$\text{Other Trip Length} = 0.00219 * \left[p^{0.18} * S_2^{1.40} + p^{0.26} * S_2^{1.25} \right] \qquad \text{(in miles)}$$

where: p = Future Population

S_1 = Average network vehicle speed for work trips in miles per hour

S_2 = Average network vehicle speed for other trips in miles per hour

Next, determine a value for the proportion of Work and Other Trip Lengths that are less than the Effective Radius (default = 0.40). Enter data on the next four lines from Worksheets 6 and 7 and compute values for the VMT variables. Next, enter the proportion of VMT occurring in the peak hour of the day (default = 0.10). The proportion of off-peak hour VMT is 1 minus the peak hour proportion (default = 0.90). Next, enter the proportions of VMT traveled on three facility types (expressways, arterials, local streets) for

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*To convert to kilometers for Worksheet 7M, multiply by 1.609.

TABLE 2-6

DEFAULT TRIP GENERATION RATES*

Land Use Type	Trips Per Day Per Measure	Work Trip Rates	Other Trip Rates
Single Family Detached	Dwelling Units	1.8	9.0
Single Family Attached	Dwelling Units	1.5	7.0
Multiple Family	Dwelling Units	1.0	5.0
Large Commercial	1,000 Square Feet (Square Meters)	0	40 (0.43)
Medium Commercial	1,000 Square Feet (Square Meters)	0	64 (0.69)
Small Commercial	1,000 Square Feet (Square Meters)	0	67 (7.2)
Office - Professional	1,000 Square Feet (Square Meters)	16 (0.17)	0
Manufacturing	1,000 Square Feet (Square Meters)	5.0 (0.05)	0
Wholesale	1,000 Square Feet (Square Meters)	4.0 (0.04)	0
Education	1,000 Square Feet (Square Meters)	0	4.0 (0.04)
Other	1,000 Square Feet (Square Meters)	0.13 (0.0013)	5.0 (0.05)
Recreation	Acres (Square Meters)	0	42 (169,970)

*Values in parentheses are in metric units.

Work and Other type trips. The six proportions must sum to 1.0. If local transportation data are unavailable, estimates can be made using the procedure described in Volume III of the GEMLUP-I final report [11], or by using methods presented in other standard publications [20,21]. Next, enter average speeds for peak and off-peak hours, and the three facility types. If local data are not available, default values are provided. Next, copy the indicated trip data from Worksheet 6 and compute Sum A and Sum B. These are used to calculate the Heavy Duty Correction factor, and finally, the proportion of vehicles in various classes[1].

Worksheet 8 is used to compute VMT by various categories of area, time of day and facility type. Enter VMT data in the columns indicated with arrows, enter proportion data on the appropriate lines from boxes on Worksheet 7, and perform the indicated arithmetic operations.

c. Calculation of Mobile Source Emissions

The methodology for computing vehicular emissions is derived from the EPA publication Mobile Source Emission Factors [19]. Since the worksheets in this section rely heavily upon the data in that publication, it is essential that a copy be available before beginning the calculations. A computer program is available that calculates composite emission factors using data from reference 19, and so could be substituted for Worksheets 9 and 10. A copy of this program can be obtained from the Office of Transportation and Land Use Policy, U.S. Environmental Protection Agency, AW-445, 401 M Street S.W., Washington, D.C., 20460 (202-755-0603).

Worksheet 9 is used to compute an average emission factor (in grams per mile, or grams per kilometer) for a given set conditions involving vehicle type, speed and pollutant. Since there are 4[2] vehicle types, 6 vehicle speeds (reflecting peak or off peak hours, in conjunction with 3 facility types), and 3 pollutants[3], it is necessary to fill out 72 separate copies of Worksheet 9 for a given area of analysis. If one representative speed for the entire area is used, the total number will be reduced to only 12, but the results will necessarily be less accurate. The first step in completing Worksheet 9 is to record carefully all of the descriptive data requested at the top of the worksheet. Next, fill in the model years in column (2), starting with t + 10 and decreasing down to t - 2. Values for columns (3), (4), (6) and (7)[4] should be transcribed from the EPA publication [19][5]. Next, compute the Total Emission Rate in column (5) by summing columns (3) and (4). The Model Year Total Emissions in column (8) are then obtained by taking the product of columns (5), (6), and (7). The average emission factor is the sum of column (8).

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[1] Note a proportion value for Light Duty Truck/Gas is not calculated since a fixed value of 0.118 is used.

[2] Emission factors for motorcycles are not included in the worksheets since these are usually negligible in an area total. If a particular case study contains relatively large amounts of motocycle traffic, emissions can be calculated using the procedures in reference [19].

[3] There are really five criteria pollutants which motor vehicles emit. However, average emission factors for particulates and sulfur oxides are relatively invariable. Appropriate values are listed in Table 2-7.

[4] There are other correction factors for such things as air conditioning (A_{ip}), vehicle load (L_p), trailer towing (U_{ipw}), and humidity (H_{ip}). These correction factors make little difference in composite emissions, thus we have not included them in the worksheets. If deemed significant, the emissions can be corrected using the procedures in reference [19].

[5] When using Worksheet 9M, use the metric value for C_{ipn}, in grams per kilometer.

TABLE 2-7

PARTICULATE AND SULFUR OXIDE EMISSION FACTORS

Vehicle Type	Particulates gr/mi	Particulates gr/km	Sulfur Oxides gr/mi	Sulfur Oxides gr/km
Automobile/Gas	0.54 (0.25)*	0.33 (0.15)*	0.13	0.08
Light Duty Truck/Gas	0.54 (0.25)*	0.33 (0.15)*	0.18	0.11
Heavy Duty/Gas	1.31+	0.81+	0.36	0.22
Heavy Duty/Diesel	1.31	0.81	2.80	1.70

*Unleaded gasoline

+Assumes an average of 8 tires per vehicle

Source: [22].

Worksheet 10 is used to calculate a composite emission factor for a given combination of vehicle speed and pollutant. Since there are 6 vehicle speeds and 5 pollutants, it is necessary to fill out 30 separate copies of Worksheet 10. The first step in completing Worksheet 10 is to again carefully record the descriptive data requested at the top. Next, enter the appropriate Average Emission Factors from Worksheets 9 and the vehicle class proportions from the bottom of Worksheet 7. Emission factors for sulfur oxides and particulates are listed in Table 2-7. Column (3) is the product of columns (1) and (2). Compute the Composite Emission Factor by summing column (3).

Worksheet 11 is used to calculate Total Motor Vehicle Emissions in both the Area of Analysis and the Impact Area for a given pollutant. Since there are 5 pollutants, it is necessary to fill out 5 separate copies of Worksheet 11. The first step is to record the pollutant at the top of the worksheet. Next, Average Route Speeds from Worksheet 7, corresponding to the various conditions, should be listed in column (1) and VMT data from Worksheet 8 should be listed in column (2). Next, record in column (3) the values for Composite Emission Factors from Worksheets 10. Total Emissions in column (4) are computed by taking the product of columns (2) and (3). Area of Analysis and Impact Area totals are then obtained by summing column (4) in two parts and multiplying by the units correction factor of 0.805.

d. Emission Summary

The emission estimates provided by the worksheets in this section are totals for an entire year (in pounds or kilograms of pollutant) in both the Area of Analysis and the Impact Area. These emission projections correspond to conditions in year t + 10.

Worksheet 12 is used to calculate Stationary Source Emissions for a given combination of fuel type (oil, gas, or electricity) and pollutant. Since the first two fuel types each generate 5 types of pollutants, 10 combinations result. When electricity is the fuel, the only "pollutant" is kilowatt-hours (which are later converted to air pollutant emissions at an off-site generating plant). Thus, it is necessary to fill out 11 separate copies of Worksheet 12. The first step in completing Worksheet 12 is to record the fuel type and pollutant at the top of the worksheet. Next, enter the amounts of total land use in column (1) from Worksheet 6 (note, Total Manufacturing Land Use is recorded at the bottom). Next, determine for each land use type, the proportion of the total that will be using the fuel which is recorded at the top of the worksheet (i.e., this should be a value between 0.0 and 1.0) and enter these values in column (2). Note that for a given land use type, the proportion values used in the 11 copies of this worksheet must sum to 1.0. If local data are not available, national statistics from the U.S. Census [23,24] may be used instead. Next, record the process, space heating, and space cooling emission factors in columns (3), (5), and (7), respectively. These values can be obtained from Tables 2-8 through 2-13*. The space heating and space cooling emission factors must first be multiplied by the appropriate degree-day or operating-hour statistics, displayed in Figures 2-2 through 2-4. Next, a composite Industrial Emission Factor, based on the expected mix of SIC codes in manufacturing development, should be computed from Table 2-14 and recorded at the bottom of the worksheet. Process Emissions, in column (4), are calculated by taking the product of columns (1), (2), and (3). Space Heating Emissions, in column (6), are the product of columns (1), (2) and (5), while Space Cooling Emissions in column (8) are obtained by multiplying columns (1), (2), and (7). Columns (4), (6), and (8) are then separately summed to obtain Total Process, Space Heating and Space Cooling Emissions, respectively. Total Industrial Emissions are obtained by performing the indicated multiplication.

Worksheet 13 is used to calculate total emissions (in pounds/year or kilograms/year) for each of the 5 criteria pollutants in both the Area of Analysis and the Impact Area. First, summarize the 11 copies of Worksheet 12 in rows (1) through (4) and sum to obtain Total Stationary Source Emissions in row (5). Next, record the values of Total Motor Vehicle Emissions from Worksheet 11 in rows (6) and (11). Compute the Total Emissions, Area of Analysis, in row (7), as the sum of rows (5) and (6). Next, enter values for the Electric Utility Emission Factors in row (8), from either local data or Table 2-15 (assuming either coal, oil, or gas powered generators). Then, bring the value for Total Kilowatt-Hours down and record it in each blank in row (9). The Electric Utility Emissions, in row (10), is then just the product of rows (8) and (9). Compute the Total Emissions, Impact Area, in row (12), as the sum of rows (5), (10), and (11).

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*If Worksheet 12M is used, all of these emission factors must be converted from pounds to kilograms by multiplying by 0.454.

TABLE 2-8

SINGLE FAMILY DETACHED OR ATTACHED LAND USE BASE EMISSION FACTORS

	pound of pollutant (or kilowatt-hours) per measure						
	PM	SO_x	CO	HC	NO_x	kWh	Measure
Space Heating							
Electricity	-	-	-	-	-	3.8	dwelling unit·ht.d.d.
Gas	2.6×10^{-4}	1.5×10^{-5}	5.1×10^{-4}	2.0×10^{-4}	2.6×10^{-3}	-	dwelling unit·ht.d.d.
Oil	2.2×10^{-3}	$3.2 \times 10^{-2}S$	1.1×10^{-3}	6.6×10^{-4}	2.6×10^{-3}	-	dwelling unit·ht.d.d.
Air Conditioning							
Central							
Electricity	-	-	-	-	-	4.7	dwelling unit·op.hr.
Gas	1.8×10^{-4}	1.1×10^{-5}	3.5×10^{-4}	1.4×10^{-4}	1.8×10^{-3}	-	dwelling unit·op.hr.
Room							
Electricity	-	-	-	-	-	5.1×10^{-1}	a.c. unit·operating hour
Process							
Hot Water							
Electricity	-	-	-	-	-	$1.4 \times 10^{+4}$	dwelling unit·year
Gas	3.0×10^{-1}	1.8×10^{-2}	6.0×10^{-1}	2.4×10^{-1}	3.0	-	dwelling unit·year
Oil	2.5	$3.7 \times 10^{-1}S$	1.2	7.5×10^{-1}	3.0	-	dwelling unit·year
Cooking							
Electricity	-		-	-	-	$3.5 \times 10^{+3}$	dwelling unit·year
Gas	1.1×10^{-1}	6.6×10^{-3}	2.2×10^{-1}	8.8×10^{-2}	1.1		dwelling unit·year
Miscellaneous	-	-	-	-	-	$7.9 \times 10^{+3}$	dwelling unit·year

Note: A 1600 square foot dwelling unit is assumed.

'S' represents the percent sulfur in oil, by weight.

TABLE 2-9

MULTIPLE FAMILY LAND USE BASED EMISSION FACTORS

Activity	pound of pollutant (kilowatt-hours) per measure						
	PM	SO_x	CO	HC	NO_x	kWh	Measure
Space Heating							
Electricity	-	-	-	-	-	1.3	dwelling unit·ht.d.d.
Gas	1.2×10^{-4}	7.3×10^{-6}	2.4×10^{-4}	9.7×10^{-5}	1.2×10^{-3}	-	dwelling unit·ht.d.d.
Oil	1.1×10^{-3}	$1.7 \times 10^{-2}S$	5.7×10^{-4}	3.4×10^{-4}	1.4×10^{-3}	-	dwelling unit·ht.d.d.
Air Conditioning							
Central							
Electricity	-	-	-	-	-	1.5	dwelling unit·op.hr.
Gas	6.2×10^{-5}	3.7×10^{-6}	1.2×10^{-4}	5.0×10^{-5}	6.2×10^{-4}	-	dwelling unit·op.hr.
Oil	4.5×10^{-4}	6.4×10^{-3}	2.2×10^{-4}	1.3×10^{-4}	5.3×10^{-4}	-	dwelling unit·op.hr.
Room							
Electricity	-		-	-	-	5.1×10^{-1}	a.c. unit·op.hr.
Process							
Hot Water							
Electricity	-	-	-	-	-	$1.1 \times 10^{+4}$	dwelling unit·year
Gas	2.4×10^{-1}	1.4×10^{-2}	4.8×10^{-1}	1.9×10^{-1}	2.4	-	dwelling unit·year
Oil	2.0	$2.9 \times 10^{+1}S$	1.0	6.0×10^{-1}	2.4	-	dwelling unit·year
Cooking & Dryer							
Electricity	-	-	-	-	-	$3.8 \times 10^{+3}$	dwelling unit·year
Gas	1.2×10^{-1}	7.2×10^{-3}	2.4×10^{-1}	9.6×10^{-2}	1.2	-	dwelling unit·year
Miscellaneous	-	-	-	-	-	$4.4 \times 10^{+3}$	dwelling unit·year

Note: A 900 square foot dwelling unit is assumed.

'S' represents the percent sulfur in oil, by weight.

TABLE 2-10

COMMERCIAL AND WHOLESALE LAND USE BASED EMISSION FACTORS

Activity	pound of pollutant (or kilowatt-hours) per measure						Measure
	PM	SO_x	CO	HC	NO_x	kWh	
Space Heating							
Electricity	-	-	-	-	-	1.3	$10^3 ft^2$ ·ht.d.d.
Gas	9.8×10^{-5}	5.9×10^{-6}	2.0×10^{-4}	7.8×10^{-5}	9.8×10^{-4}	-	$10^3 ft^2$ ·ht.d.d.
Oil	1.7×10^{-3}	$1.2 \times 10^{-2} S$	2.9×10^{-4}	3.3×10^{-2}	4.4×10^{-3}	-	$10^3 ft^2$ ·ht.d.d.
Air Conditioning							
Electricity	-	-	-	-	-	5.2	$10^3 ft^2$ ·cl.d.d.
Process							
Hot Water							
Electricity	-	-	-	-	-	5.0×10^2	$10^3 ft^2$ ·year
Gas	2.4×10^{-2}	1.4×10^{-3}	4.8×10^{-2}	1.9×10^{-2}	2.4×10^{-1}	-	$10^3 ft^2$ ·year
Oil	5.2×10^{-1}	3.6 S	9.1×10^{-2}	$1.0 \times 10^{+1}$	1.4	-	$10^3 ft^2$ ·year
Lighting	-	-	-	-	-	8.0×10^3	$10^3 ft^2$ ·year
Auxiliary Equipment	-	-	-	-	-	3.6×10^3	$10^3 ft^2$ ·year
Appliances	-	-	-	-	-	2.0×10^3	$10^3 ft^2$ ·year
Refrigeration	-	-	-	-	-	8.9×10^3	$10^3 ft^2$ ·year

Note: 'S' represents the percent sulfur in oil, by weight.

TABLE 2-11

OFFICE-PROFESSIONAL LAND USE BASED EMISSION FACTORS

	pound of pollutant (or kilowatt-hours) per measure						
Activity	PM	SO_x	CO	HC	NO_x	kWh	Measure
Space Heating							
Electricity	-	-	-	-	-	1.9	$10^3 ft^2 \cdot$ ht.d.d.
Gas	9.4×10^{-5}	5.6×10^{-6}	1.9×10^{-4}	7.5×10^{-5}	9.4×10^{-4}	-	$10^3 ft^2 \cdot$ ht.d.d.
Oil	1.7×10^{-3}	$1.2 \times 10^{-2} S$	2.9×10^{-4}	3.3×10^{-2}	4.4×10^{-3}	-	$10^3 ft^2 \cdot$ ht.d.d.
Air Conditioning							
Electricity	-	-	-	-	-	1.5	$10^3 ft^2 \cdot$ cl.d.d.
Gas	7.4×10^{-5}	4.4×10^{-6}	1.5×10^{-4}	5.9×10^{-5}	7.4×10^{-4}	-	$10^3 ft^2 \cdot$ cl.d.d.
Oil	1.3×10^{-3}	$9.1 \times 10^{-3} S$	2.3×10^{-4}	2.6×10^{-2}	3.4×10^{-3}	-	$10^3 ft^2 \cdot$ cl.d.d.
Process	-	-	-	-	-	$2.8 \times 10^{+4}$	$10^3 ft^2 \cdot$ year

Note: 'S' represents the percent sulfur in oil, by weight.

TABLE 2-12

EDUCATION LAND USE BASED EMISSION FACTORS

Activity	pound of pollutant (or kilowatt-hours) per measure						Measure
	PM	SO_x	CO	HC	NO_x	kWh	
Space Heating							
Electricity	-	-	-	-	-	1.7	$10^3 ft^2 \cdot$ ht.d.d.
Gas	8.0×10^{-5}	4.8×10^{-6}	1.6×10^{-4}	6.4×10^{-5}	8.0×10^{-4}	-	$10^3 ft^2 \cdot$ ht.d.d.
Oil	1.2×10^{-3}	8.5×10^{-3}	2.1×10^{-4}	2.4×10^{-2}	3.2×10^{-3}	-	$10^3 ft^2 \cdot$ ht.d.d.
Air Conditioning							
Electricity	-	-	-	-	-	4.7×10^{-1}	$10^3 ft^2 \cdot$ cl.d.d.
Gas	2.3×10^{-5}	1.4×10^{-6}	4.6×10^{-5}	1.8×10^{-5}	2.3×10^{-4}	-	$10^3 ft^2 \cdot$ cl.d.d.
Oil	4.1×10^{-4}	2.8×10^{-3}	7.1×10^{-5}	8.0×10^{-3}	1.1×10^{-3}	-	$10^3 ft^2 \cdot$ cl.d.d.
Process	-	-	-	-	-	7.1×10^3	$10^3 ft^2 \cdot$ year

Note: 'S' represents the percent sulfur in oil, by weight,

TABLE 2-13

OTHER LAND USE BASED EMISSION FACTORS

Activity	pound of pollutant (or kilowatt-hours) per measure						
	PM	SO_x	CO	HC	NO_x	kWh	Measure
Space Heating							
Electricity	-	-	-	-	-	1.7	$10^3 ft^2 \cdot$ht.d.d.
Gas	9.4×10^{-5}	5.6×10^{-6}	1.9×10^{-4}	7.5×10^{-5}	9.4×10^{-4}	-	$10^3 ft^2 \cdot$ht.d.d.
Oil	1.4×10^{-3}	$9.9 \times 10^{-3} S$	2.5×10^{-4}	2.8×10^{-2}	2.8×10^{-2}	-	$10^3 ft^2 \cdot$ht.d.d.
Air Conditioning							
Electricity	-	-	-	-	-	4.7×10^{-1}	$10^3 ft^2 \cdot$cl.d.d.
Gas	2.3×10^{-5}	1.4×10^{-6}	4.6×10^{-5}	1.8×10^{-5}	2.3×10^{-4}	-	$10^3 ft^2 \cdot$cl.d.d.
Oil	4.1×10^{-4}	$2.8 \times 10^{-3} S$	7.1×10^{-5}	8.0×10^{-3}	1.1×10^{-3}	-	$10^3 ft^2 \cdot$cl.d.d.
Process	-	-	-	-	-	$1.2 \times 10^{+4}$	$10^3 ft^2 \cdot$year

Note: 'S' represents the percent sulfur in oil, by weight.

TABLE 2-14

ESTIMATED NATIONAL INDUSTRIAL LAND USE BASED EMISSION FACTORS BY TWO DIGIT 1967 STANDARD INDUSTRIAL CLASSIFICATION CODE

Pounds of pollutant (or KWH of electricity) per $10^3 ft^2$ floor area per year

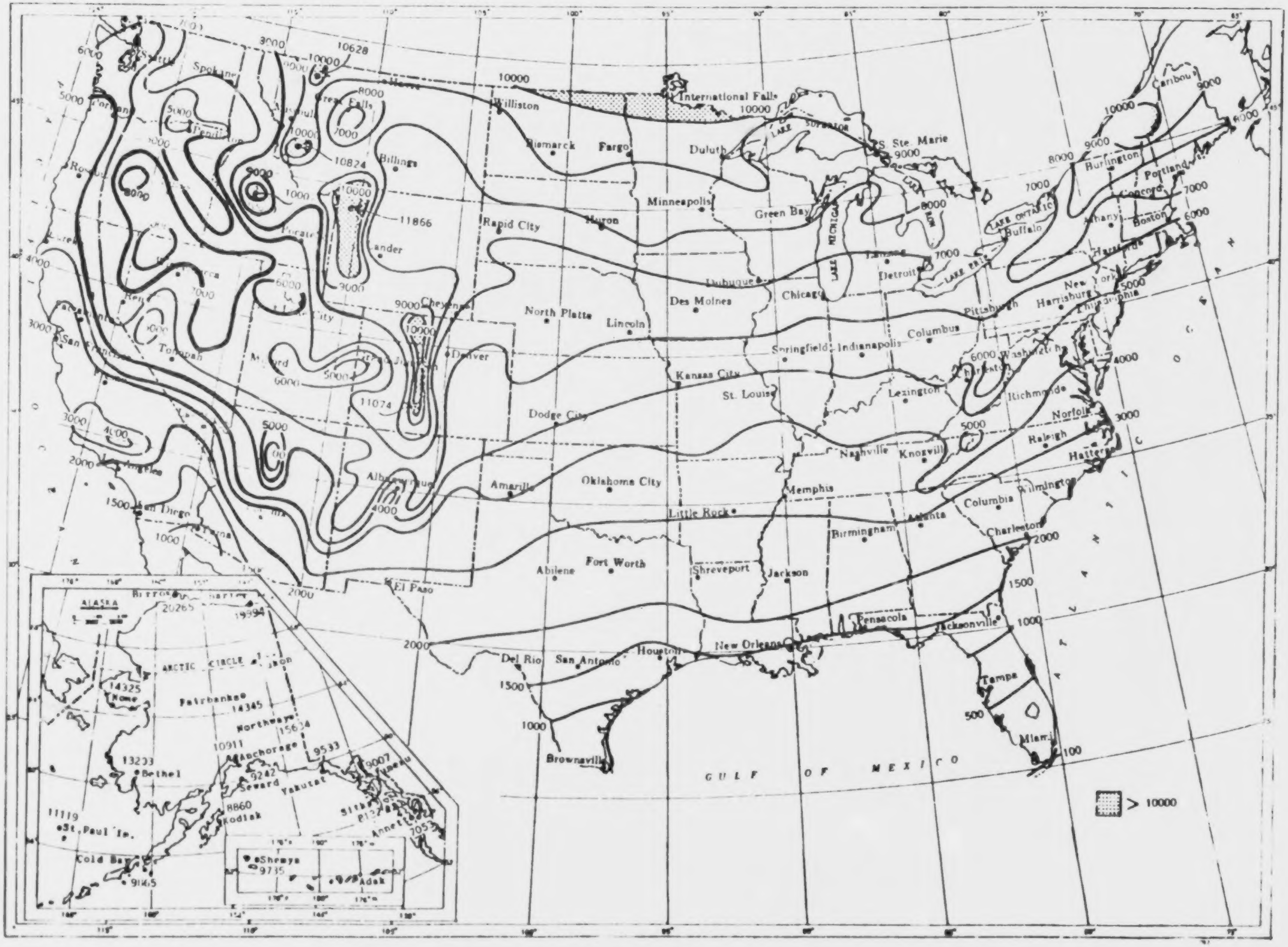
SIC Code	Particulates	SO_x	CO	HC	NO_x	KwH
20	640	500	13	3.3	130	38,000
21	1220	1020	25	14	230	48,000
22	580	540	14	8.1	140	68,000
23	60	40	1.4	0.84	15	16,000
24	60	70	3.4	2.3	45	22,000
25	110	80	2.2	1.2	21	14,000
26	3120	3090	69	40	690	85,000
27	10	20	0.68	0.48	9.5	25,000
28	100	460	11	8.1	160	181,000
29	1060	2780	55	38	730	426,000
30	510	380	10	5.8	97	50,000
31	170	170	4.7	2.9	52	18,000
32	4030	2670	720	38	610	78,000
33	3060	2380	61	34	570	297,000
34	140	120	3.5	2.1	36	33,000
35	220	180	4.7	2.7	46	31,000
36	220	200	5.3	3.2	56	56,000
37	680	480	13	6.8	110	54,000
38	950	700	18	9.5	150	38,000
10 & 39	80	130	3.5	2.4	44	31,000

Note: The following is assumed:
2% sulfur in coal
10% ash in coal

0.2% sulfur in distillate oil
1.75% sulfur in residual oil

1967 SIC codes are used because of data availability. The 1972 SIC code manual provides conversions between 1967 and 1972 codes [25].

Figure 2-2: NORMAL SEASONAL HEATING DEGREE DAYS (BASE 65°F) 1941–1970



Seattle
Spokane
Portland
Roseburg
Eureka
Reno
Sacramento
San Francisco
Tonopah
Los Angeles
San Diego
Yuma
Pendleton
Missoula
Great Falls
Havre
Billings
Pocatello
Lander
Salt Lake City
Milford
Grand Junction
Cheyenne
Denver
Albuquerque
El Paso
Williston
Bismarck
Fargo
Rapid City
Huron
North Platte
Lincoln
Dodge City
Amarillo
Oklahoma City
Abilene
Fort Worth
Del Rio
San Antonio
Houston
Brownsville
International Falls
Duluth
Minneapolis
Green Bay
Des Moines
Dubuque
Chicago
Kansas City
St. Louis
Springfield
Indianapolis
Little Rock
Shreveport
Jackson
Memphis
New Orleans
Nashville
Knoxville
Birmingham
Atlanta
Pensacola
Jacksonville
Tampa
Miami
S. Ste. Marie
Lansing
Detroit
Columbus
Lexington
Charleston
Pittsburgh
Buffalo
Albany
Harrisburg
New York
Philadelphia
Washington
Richmond
Raleigh
Norfolk
Hatteras
Wilmington
Columbia
Charleston
Burlington
Concord
Portland
Boston
Hartford
Caribou
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
GULF OF MEXICO
ATLANTIC OCEAN
PACIFIC OCEAN
10628
10824
11866
11074
10000
9000
8000
7000
6000
5000
4000
3000
2000
1500
1000
500
100
ALASKA
Barrow
20265
19994
ARCTIC CIRCLE
Nome
14325
Fairbanks
14345
Northway
15634
Anchorage
10911
9533
9007
Juneau
Bethel
13203
Seward
9242
Yakutat
Kodiak
8860
Sitka
Annette
7053
11119
St. Paul Is.
Cold Bay
9145
Shemya
9735
Adak
> 10000

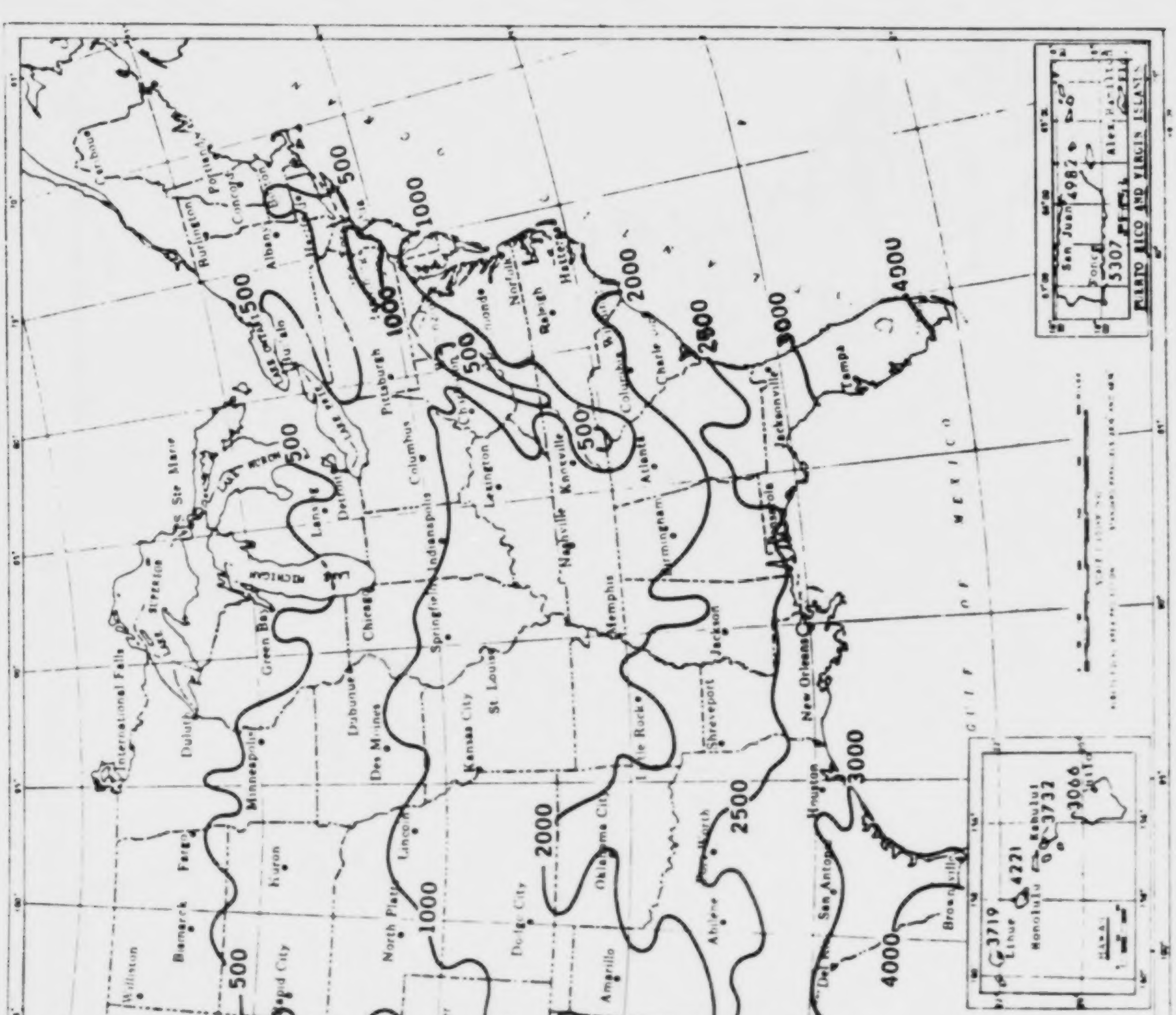

500
1000
2000
2500
3000
4000
Seattle
Portland
Spokane
Great Falls
Missoula
Billings
Lander
Cheyenne
Denver
Grand Junction
Salt Lake City
Pocatello
Boise
Reno
Fresno
Williston
Bismarck
Rapid City
Fargo
Huron
North Platte
Dodge City
Amarillo
Albuquerque
El Paso
Phoenix
Abilene
San Antonio
Brownsville
Houston
Fort Worth
Oklahoma City
Lincoln
Kansas City
Des Moines
Dubuque
Minneapolis
Duluth
International Falls
Green Bay
Chicago
Springfield
St. Louis
Little Rock
Shreveport
Jackson
New Orleans
Memphis
Nashville
Birmingham
Atlanta
Knoxville
Lexington
Indianapolis
Columbus
Detroit
Lansing
Sault Ste Marie
Pittsburgh
Buffalo
Albany
Burlington
Portland
Concord
Caribou
Raleigh
Norfolk
Hatteras
Charleston
Jacksonville
Tampa
Columbia
GULF OF MEXICO
Fairbanks 52
Nome
Barrow
Barter
Anchorage
Bethel
St. Paul Is.
Cold Bay
Kodiak
Sitka
ARCTIC CIRCLE
Lihue 3719
Honolulu 4221
Kahului 3732
3066
HAWAII
San Juan 4982
Ponce 5307
PUERTO RICO AND VIRGIN ISLANDS

Figure 2-3: NORMAL SEASONAL COOLING DEGREE DAYS (BASE 65°F) 1941–1970

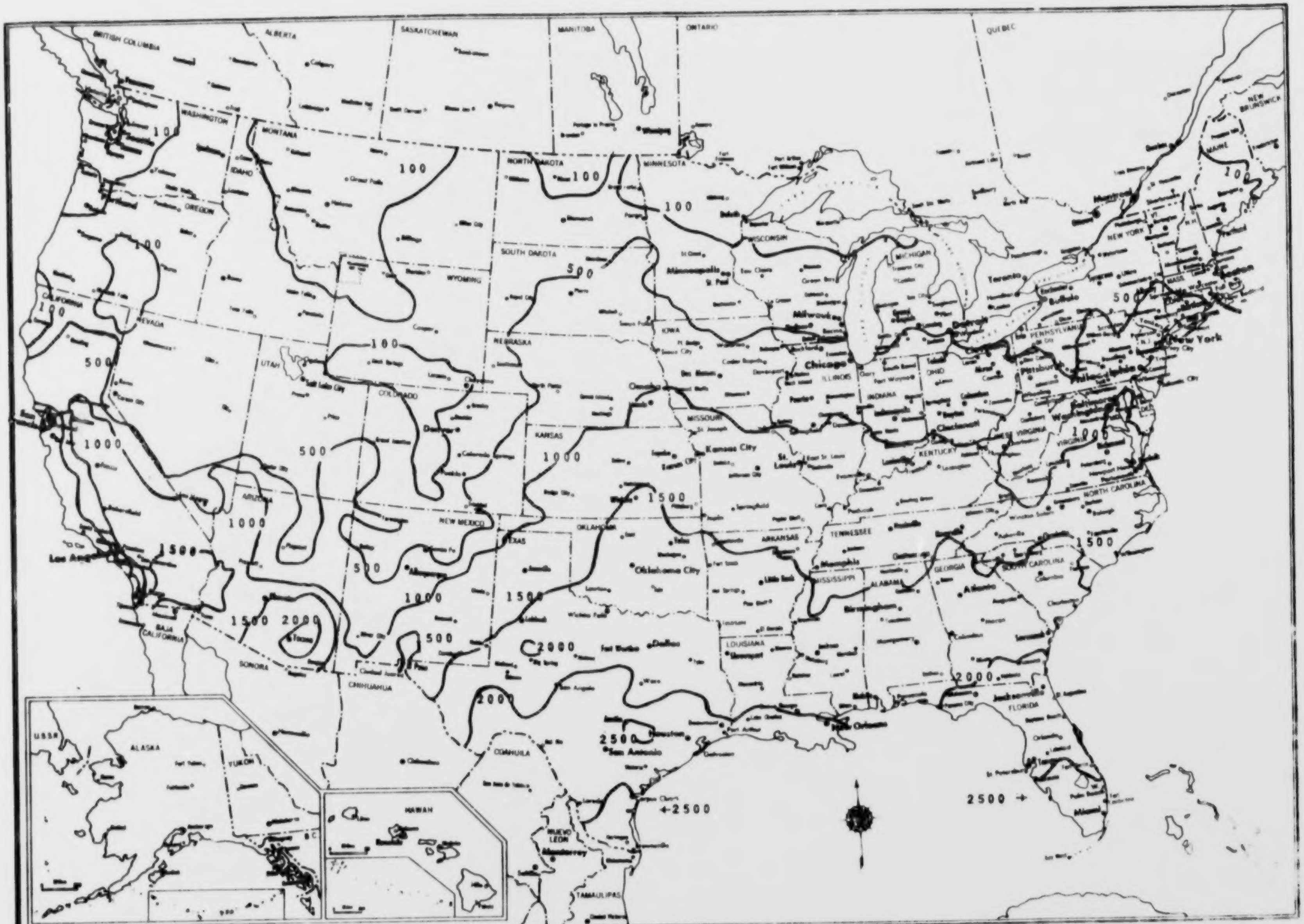

100
500
1000
1500
2000
2500
+2500
2500 +
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEW BRUNSWICK
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
WISCONSIN
MICHIGAN
NEW YORK
SOUTH DAKOTA
WYOMING
NEVADA
UTAH
NEBRASKA
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
COLORADO
KANSAS
MISSOURI
KENTUCKY
VIRGINIA
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSAS
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
TEXAS
MISSISSIPPI
ALABAMA
GEORGIA
LOUISIANA
FLORIDA
BAJA CALIFORNIA
SONORA
CHIHUAHUA
COAHUILA
NUEVO LEON
TAMAULIPAS
ALASKA
YUKON
USSR
HAWAII
Minneapolis
St. Paul
Milwaukee
Chicago
Toronto
Buffalo
New York
Philadelphia
Pittsburgh
Detroit
Kansas City
St. Louis
Denver
Salt Lake City
Los Angeles
Oklahoma City
Fort Worth
Dallas
Memphis
Little Rock
Atlanta
Birmingham
New Orleans
Houston
San Antonio
Jacksonville
Miami
Monterrey

FIGURE 2-4: ANNUAL AIR CONDITIONER COMPRESSOR-OPERATING HOURS FOR HOMES THAT ARE NOT NATURALLY VENTILATED.

TABLE 2-15

TYPICAL UNCONTROLLED EMISSION FACTORS FOR ELECTRIC UTILITIES

	lbs. emissions per kWh sold to customer				
	PM	SO_x	CO	HC	NO_x
coal	$5.23 \times 10^{-3}A$	$1.53 \times 10^{-2}S$	4.03×10^{-4}	1.21×10^{-4}	2.21×10^{-2}
oil	6.34×10^{-4}	$1.26 \times 10^{-2}S$	2.38×10^{-4}	1.58×10^{-4}	8.32×10^{-3}
gas	1.19×10^{-4}	7.13×10^{-6}	2.02×10^{-4}	1.19×10^{-5}	8.32×10^{-3}

Note: A 33.3% overall plant efficiency is assumed for coal-fired plants [26].
A 31.6% overall plant efficiency is assumed for oil- and gas-fired plants [26].
A 10% transmission loss is assumed [27].
'S' and 'A' represent, respectively, the percent sulfur and ash in the fuel by weight.

4. English Unit Worksheets

Summarized in this section are all English unit worksheets. Metric unit worksheets begin on Page 2-60.

WORKSHEET 1

INPUT DATA RECORD IN ENGLISH UNITS

Variable Name	Value/Computation	Inputs To Worksheets	Units
Area of Analysis	________	= ☐	Acres
Vacant Developable	________		Acres
Vacant Undevelopable	________		Acres
Vacant Land	= Vacant Developable ÷ (Area of Analysis - Vacant Undevelopable)	= ☐	*
Median Price	________		$
Median Income	________		$
Land Cost	= Median Price ÷ Median Income	= ☐	*
Collection Capacity	________		Million Gallons Per Day
Peak Flow	________	= ☐	Million Gallons Per Day
% Collection Reserve	= 100* (Collection Capacity - Peak Flow) ÷ Peak Flow	= ☐	*
Manufacturing Workers	________		Employees
Tract Area	= ________		Square Miles
Manufacturing Density	= Manufacturing Workers ÷ Tract Area	= ☐	Employees Per Square Mile
Nonmobility	________	= ☐	*
Drivers	________		100s of Drivers
County Area	________		Square Miles
Driver Density	= Drivers ÷ County Area	= ☐	100s of Drivers Per Square Mile
Sewered Land	________		Acres
Sewer Service	= Sewered Land ÷ Area of Analysis	= ☐	*
School Kids	________		Children
Dwelling Units	________		100s of Dwelling Units
Kid Density	= Schools Kids ÷ Dwelling Units	= ☐	Children Per 100 Dwelling Units
Limited Access	________		Interchanges
Interchanges	= 640* Limited Access ÷ Area of Analysis	= ☐	Interchanges Per Square Mile
Current Employment	________		Employees
Future Employment	________		Employees
SMSA Area	________		Square Miles
Employment Growth	= (Future Employment - Current Employment) ÷ SMSA Area	= ☐	Employees Per Square Mile
Track	________		Miles
Railroads	= 640* Track ÷ Area of Analysis	= ☐	Railroad Miles Per Square Mile Land Area
Zoned Office	________		Acres

*Unitless

WORKSHEET 1 (CONTINUED)

INPUT DATA RECORD IN ENGLISH UNITS

Variable Name	Value/Computation	Inputs to Worksheets	Units
Office Zoning	= Zoned Office : Area of Analysis	= ☐	*
House Density	= 100* Dwelling Units : Tract Area	= ☐	Dwelling Units Per Square Mile
Zoned Industrial	______		Acres
Industrial Zoning	= Zoned Industrial : Area of Analysis	= ☐	*
Population Growth	______	= ☐	*
Office Vacancy	______	= ☐	*
Airport Distance	______	= ☐	Miles
Office Workers	______		Employees
Office Employees	= Office Workers ÷ Tract Area	= ☐	Employees Per Square Mile
Future Population	______		People
Employee Ratio	= Future Employment ÷ Future Population	= ☐	*
Unemployment	______	= ☐	*
Future Income	______	☐	$
Government	______	☐	Millions of $
Collection Reserve	= Collection Capacity - Peak Flow	= ☐	Million Gallons Per Day
Interceptors	______		Miles
Interceptor Density	= 640* Interceptors ÷ Area of Analysis	= ☐	Miles of Interceptor Pipe Per Square Mile Land Area
Poverty	______	= ☐	*
Onsite Restrictions	______	= ☐	*
County Growth	______	= ☐	*
Project Cost	______		Thousand $
Federal Funds	______		Thousand $
Index One	______		*
Index Two	______		*
Population Served	______		People

*Unitless

WORKSHEET 1 (CONTINUED)

INPUT DATA RECORD IN ENGLISH UNITS

Variable Name	Value/Computation	Inputs to Worksheets	Units
Sewer Costs	= 1,000* ((Project Cost ÷ Index One) - (Federal Funds ÷ Index Two)) ÷ Population Served	=	$ Per Person
Treatment Capacity		=	Million Gallons Per Day
Vacant Houses		=	*
County Interchanges			Interchanges
Interchange Density	= Interchanges ÷ (640* County Interchanges ÷ County Area)	=	*
Zoned Residential			Acres
Residential Zoning	= Zoned Residential ÷ Area of Analysis	=	*
Current Income			$
Income Growth	= Future Income - Current Income	=	$
Current Medicals			Employees
Future Medicals			Employees
Hospital Growth	= (Future Medicals - Current Medicals) ÷ Current Medicals	=	*
Current Houses			Dwelling Units
Future Houses			Dwelling Units
Housing Growth	= (Future Houses - Current Houses) ÷ Current Houses	=	*
Restriction Years		=	Years
Phasing		=	*
Transit Stops		=	*
CBD Distance		=	Miles

*Unitless

WORKSHEET 2

LAND USE PROJECTIONS

Residential = (-8692 * ______ Vacant Land) + (5347 * ______ Land Cost) + (16.42 * ______ % Collection Reserve) + (11.24 * ______ Manufacturing Density)
- (18804 * ______ Nonmobility) + (487.2 * ______ Driver Density) + 13466 = ☐ Dwelling Units Per 10,000 Acres*

Commercial = (4302 * ______ Sewer Service) - (4515 * ______ Vacant Land) - (28.84 * ______ Kid Density) + (6249 * ______ Interchanges)
- (17.04 * ______ Employment Growth) - (2.626 * ______ %Collection Reserve) + 5376 = ☐ 1,000 Square Feet Per 10,000 Acres

Office-Professional = (719.5 * ______ Railroads) + (33478 * ______ Office Zoning) + (36.70 * ______ Peak Flow) + (0.3324 * ______ House Density)
- (1791 * ______ Industrial Zoning) + (572.0 * ______ Population Growth) - 459.9 = ☐ 1,000 Square Feet Per 10,000 Acres

Manufacturing = (2591 * ______ Railroads) - (3890 * ______ Vacant Land) + (2.978 * ______ Manufacturing Density) + (85923 * ______ Office Zoning)
+ (234.7 * ______ Office Vacancy) + (22.7 * ______ Airport Distance) + 611.2 = ☐ 1,000 Square Feet Per 10,000 Acres

Wholesale = (166.5 * ______ Driver Density) + (86.28 * ______ Office Vacancy) + (3.340 * ______ Office Employees) + (6043 * ______ Employee Ratio)
+ (6949 * ______ Unemployment) - (0.1065 * ______ Future Income) - 1911 = ☐ 1,000 Square Feet Per 10,000 Acres

Highways = (35.22 * ______ Railroads) + (22.98 * ______ Land Cost) - (0.1167 ______ Government) + (0.5379 * ______ Collection Reserve)
+ (25.94 * ______ Interceptor Density) + 11.35 = ☐ Miles Per 10,000 Acres

Education = (-3.186 * ______ Poverty) + (723.0 * ______ Sewer Service) + (437.5 * ______ Land Cost) + (95.17 * ______ On-Site Restrictions)
- 405.2 * ______ County Growth) - (1.415 * ______ Sewer Costs) + 428.9 = ☐ 1,000 Square Feet Per 10,000 Acres

Recreation = (270.4 * ______ Railroads) + (2.631 * ______ Treatment Capacity) + (322.1 * ______ County Growth) + (0.9742 * ______ Office Employees)
- (3226 * ______ Vacant Houses) - (557.8 * ______ Industrial Zoning) + 59.52 = ☐ Acres Per 10,000 Acres

Other = (1134 * ______ Railroads) - (0.3020 * ______ Future Income) - (12175 * ______ Vacant Houses) + (649.0 * ______ County Growth)
- (245.4 * ______ Interchange Density) + (403.8 * ______ Residential Zoning) + 3087 = ☐ 1,000 Square Feet Per 10,000 Acres

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*10,00C Acres refers to Area of Analysis

WORKSHEET 3

FINAL LAND USE PROJECTIONS

(1) Land Use Projections From Worksheet 2	(2) Disaggregation Percentages	(3) Area of Analysis : By 10,000	(4) Final Land Use Projection (1) * (2) * (3)	(Per Area of Analysis]
Residential	% Single Family		Total Single Family Detached =	Dwelling Units
Residential	% Two Family		Total Single Family Attached =	Dwelling Units
Residential	% Multi Family		Total Multiple Family =	Dwelling Units
Commercial	% Large Commercial [1]		Total Large Commercial =	1,000 Square Feet
Commercial	% Medium Commercial [2]		Total Medium Commercial =	1,000 Square Feet
Commercial	% Small Commercial [3]		Total Small Commercial =	1,000 Square Feet
Office-Professional			Total Office-Professional =	1,000 Square Feet
Manufacturing			Total Manufacturing =	1,000 Square Feet
Wholesale			Total Wholesale =	1,000 Square Feet
Education			Total Education =	1,000 Square Feet
Other			Total Other =	1,000 Square Feet
Recreation			Total Recreation =	Acres
Highways			Total Highways =	Lane Miles

[1] Large commercial = commercial development with floor area > 100,000 ft^2.

[2] Medium commercial = commercial development with floor area between 50,000 and 100,000 ft^2.

[3] Small commercial = commercial development with floor area < 50,000 ft^2.

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WORKSHEET 4 (Optional)

DEFAULT DISAGGREGATION EQUATIONS

% Single Family = 1 ÷ (1 + 92.8 * EXP (-0.0137 * Kid Density ________ - 0.000918 * Income Growth ________ - 0.784 * Sewer Service ________
- 22.7 * Office Zoning ________ + 2.98 * Nonmobility ________ + 0.181 * Hospital Growth ________)) = ☐

% Multi Family = (1-% Single Family ________) * (1 ÷ (1 + 1.24* EXP (-438 * Housing Growth ________ + 5.48 * Poverty ________
+ 34.1 * Office Zoning ________ - 0.732 * Railroads ________ - 0.0365 * Peak Flow ________))) = ☐

% Two Family = (1-% Single Family ________ - % Multiple Family ________) = ☐

% Large Commercial = 1 ÷ (1 + 0.104 * EXP (0.215 * Office Vacancy ________ - 0.507 * Onsite Restrictions ________ + 0.0232 * Treatment Capacity ________
- 0.0159 * Kid Density ________ + 0.0603 * Restriction Years ________)) = ☐

% Medium Commercial = (1-% Large Commercial ________) * (1 ÷ (1 + 0.585 * EXP (1.54 * Phasing ________ + 0.00459 * Transit Stops ________
+ 0.0178 * CBD Distance ________ + 0.00417 * Government ________ - 1.48 * Vacant Land ________))) = ☐

% Small Commercial = (1-% Large Commercial ________ - % Medium Commercial ________) = ☐

Note: EXP is the exponential function. Thus EXP(X) = e^X.

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WORKSHEET 5 (OPTIONAL)

CONFIDENCE INTERVALS FOR PREDICTED LAND USE

Final Projected Land Use Category ______________________________

PREDICTOR VARIABLE

Name	
	1.
	2.
	3.
	4.
	5.
	6.
Constant Term	7. 1.0

COMPUTING VARIANCE OF DEPENDENT VARIABLE

Predictor Variables		Covariance Term from Appendix A		Multiplier		Resultant
① x ①	x		x	1.0	=	a.
① x ②	x		x	2.0	=	b.
① x ③	x		x	2.0	=	c.
① x ④	x		x	2.0	=	d.
① x ⑤	x		x	2.0	=	e.
① x ⑥	x		x	2.0	=	f.
① x ⑦	x		x	2.0	=	g.
② x ②	x		x	1.0	=	h.
② x ③	x		x	2.0	=	i.
② x ④	x		x	2.0	=	j.
② x ⑤	x		x	2.0	=	k.
② x ⑥	x		x	2.0	=	k'

Predictor Variables		Covariance Term from Appendix A		Multiplier		Resultant
② x ⑦	x		x	2.0	=	l.
③ x ③	x		x	1.0	=	m.
③ x ④	x		x	2.0	=	n.
③ x ⑤	x		x	2.0	=	o.
③ x ⑥	x		x	2.0	=	p.
③ x ⑦	x		x	2.0	=	q.
④ x ④	x		x	1.0	=	r.
④ x ⑤	x		x	2.0	=	s.
④ x ⑥	x		x	2.0	=	t.
④ x ⑦	x		x	2.0	=	u.
⑤ x ⑤	x		x	1.0	=	v.
⑤ x ⑥	x		x	2.0	=	w.
⑤ x ⑦	x		x	2.0	=	x.
⑥ x ⑥	x		x	1.0	=	y.
⑥ x ⑦	x		x	2.0	=	z.
⑦ x ⑦	x		x	1.0	=	aa.

Sum ⓐ through (aa) : 8. ________________

Standard Deviation of Dependent Variable = $\sqrt{⑧}$: 9. ________________

Disaggregation proportion: 10. ________________
(This is 1.0 for all land uses except residential and commercial. The proportion is the decimal equivalent of % Single Family, etc. The numbers come from Col. 2 of Worksheet 3.)

Confidence Interval (±) = ⑨ x ⑩ x 1.69 : 11. ________________

WORKSHEET 6

MOTOR VEHICLE TRIPS

Effective Radius (in miles) = 0.0223 * $\sqrt{\text{(Area of Analysis, in acres)}}$

= ________________ Miles

(1) Total Land Use	(2) Work Trip Rates	(3) Work Trips (1)*(2)	(4) Other Trip Rates	(5) Other Trips (1)*(4)
Single Family Detached				
Single Family Attached				
Multiple Family				

Residential Work Trips ________

Residential Other Trips ________

Large Commercial				
Medium Commercial				
Small Commercial				
Office-Professional				
Manufacturing				
Wholesale				
Education				
Other				
Recreation				

Total Work Trips ________

Total Other Trips ________

---

*See Page 2-26 for a definition of Effective Radius.

WORKSHEET 7

VEHICLE MILES TRAVELED (VMT)

Work Trip Length ________ Miles   Other Trip Length ________ Miles   Work Proportion ________ (Default = 0.40)   Other Proportion ________ (Default = 0.40)

VMT^*_{IW} ☐ = (Total Work Trips ________ * Work Trip Length ________) - (Residential Work Trips ________ * Work Proportion ________ * Effective Radius ________)

VMT_{AW} ☐ = (Total Work Trips ________ * Effective Radius ________) - (Residential Work Trips ________ * Work Proportion ________ * Effective Radius ________)

VMT_{IO} ☐ = (Total Other Trips ________ * Other Trip Length ________) - (Residential Other Trips ________ * Other Proportion ________ * Effective Radius ________)

VMT_{AO} ☐ = (Total Other Trips ________ * Effective Radius ________) - (Residential Other Trips ________ * Other Proportion ________ * Effective Radius ________)

Peak Hour Proportion ☐ (Default = 0.10)   Off Peak Hour Proportion ☐ (Default = 0.90)

Facility Proportions

	Work	Other
Expressways		
Arterials		
Local Streets		

Average Route Speeds (miles per hour)

Peak		Off Peak	
	(Default = 37)		(Default = 45)
	(Default = 20)		(Default = 28)
	(Default = 15)		(Default = 18)

Trip Sum A ☐ = Manufacturing Work ________ + Manufacturing Other ________ + Wholesale Work ________ + Wholesale Other ________

Trip Sum B ☐ = Total Work Trips ________ + Total Other Trips ________

HD Correction ☐ = (Sum A : Sum B) - 0.05, if less than 0, set equal to 0.

Automobile/Gas Proportion ☐ = 0.804 - HD Correction

Heavy Duty/Gas Proportion ☐ = 0.046 + 0.8 * HD Correction

Heavy Duty/Diesel Proportion ☐ = 0.032 + 0.2 * HD Correction

---

*Subscripts for VMT variables are defined as follows: I = impact area, A = area of analysis, W = work trips, O = other trips.

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[illegible]

[illegible]

AREA OF ANALYSIS $\downarrow VMT_{AW}\downarrow$ $\downarrow VMT_{AO}\downarrow$

VMT_{APE} ☐ = Peak ______ • (______ • Expressways Work ______ + ______ • Expressways Other ______)

VMT_{APA} ☐ = Peak ______ • (______ • Arterials Work ______ + ______ • Arterials Other ______)

VMT_{APL} ☐ = Peak ______ • (______ • Local Work ______ + ______ • Local Other ______)

VMT_{AOE} ☐ = Off Peak ______ • (______ • Expressways Work ______ + ______ • Expressways Other ______)

VMT_{AOA} ☐ = Off Peak ______ • (______ • Arterials Work ______ + ______ • Arterials Other ______)

VMT_{AOL} ☐ = Off Peak ______ • (______ • Local Work ______ + ______ • Local Other ______)

IMPACT AREA $\downarrow VMT_{IW}\downarrow$ $\downarrow VMT_{IO}\downarrow$

VMT_{IPE} ☐ = Peak ______ • (______ • Expressways Work ______ + ______ • Expressways Other ______)

VMT_{IPA} ☐ = Peak ______ • (______ • Arterials Work ______ + ______ • Arterials Other ______)

VMT_{IPL} ☐ = Peak ______ • (______ • Local Work ______ + ______ • Local Other ______)

VMT_{IOE} ☐ = Off Peak ______ • (______ • Expressways Work ______ + ______ • Expressways Other ______)

VMT_{IOA} ☐ = Off Peak ______ • (______ • Arterials Work ______ + ______ • Arterials Other ______)

VMT_{IOL} ☐ = Off Peak ______ • (______ • Local Work ______ + ______ • Local Work ______)

Definition of symbols used:

$\downarrow VMT_{AW}\downarrow$ The calculated work and other VMT variables derived from Worksheet 7; they are entered into the designated columns. Subscripts are defined on Worksheet 7.

VMT_{APE} VMT differentiated by type of highway and on- or off-peak. Subscripts are defined thusly:

A = area of analysis I = impact area P = peak hour O = off-peak hours
E = expressway A = arterial L = local street

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WORKSHEET 9

MOTOR VEHICLE EMISSION FACTORS

Vehicle Type = ________________ (Automobile Gas, Light Duty Truck Gas, Heavy Duty Gas, or Heavy Duty Diesel)

Pollutant = ________________ (CO, NO_x, or HC)

Region = ____________ (Low alt., High alt., or Calif.)

Speed = ________________ miles per hour

Ambient Temperature = ____________°F

Year of Impact Assessment (t+10) = ____________

Cold Starts = ________% Hot Starts = ________%

(1) Vehicle Age (Years)	(2) Model Year	(3) Base Emission Rate (C_{ipn})	(4)* Hydrocarbon Crankcase/ Evaporate Emission Rate (H_i)	(5) Total Emission Rate (3)+(4)	(6) Fraction of Travel (m_{in})	(7) Speed/Temp./Cold-Hot Starts Correction Factor (r_{ipstwx})	(8) Model Year Total Emissions (5)*(6)*(7)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
≥13							

*Note H_i = 0 for CO and NO_x; for these pollutants, enter the values for C_{ipn} directly in column (5).

Average Emission Factor ______________

WORKSHEET 10

COMPOSITE MOTOR VEHICLE EMISSION FACTORS

Speed ______________ (miles per hour)

Pollutant ______________ (CO, NO_x, HC, SO_x or Particulates)

Vehicle Class	(1) Average Emission Factor	(2) Vehicle Class Proportion	(3) Product (1)*(2)
Automobile/Gas			
Light Duty Truck/Gas		0.118	
Heavy Duty/Gas			
Heavy Duty/Diesel			

Composite Emission Factor __________

WORKSHEET 11

TOTAL MOTOR VEHICLE EMISSIONS

Pollutant ____________________

Condition	(1) Average Speed	(2) VMT Data	(3) Emission Factors	(4) Total Emissions (2)*(3)
Peak, Expressways		VMT_{APE}		
Peak, Arterials		VMT_{APA}		
Peak, Local Streets		VMT_{APL}		
Off Peak, Expressways		VMT_{AOE}		
Off Peak, Arterials		VMT_{AOA}		
Off Peak, Local Streets		VMT_{AOL}		
			Sum	
			*	0.805
Area of Analysis, Total Motor Vehicle Emissions			=	
			(in pounds/year)	
Peak, Expressways		VMT_{IPE}		
Peak, Arterials		VMT_{IPA}		
Peak, Local Streets		VMT_{IPL}		
Off Peak, Expressways		VMT_{IOE}		
Off Peak, Arterials		VMT_{IOA}		
Off Peak, Local Streets		VMT_{IOL}		
			Sum	
			*	0.805
Impact Area, Total Motor Vehicle Emissions			=	
			(in pounds/year)	

WORKSHEET 12

STATIONARY SOURCE EMISSIONS

Fuel Type ______________ (Gas, Oil, or Electricity)   Pollutant ___________ (CO, HC, NO_x, SO_x, Particulates, or Kwh)

(1) Total Land Use	(2) Fuel Proportion	(3) Process Emission Factor	(4) Process Emissions (1)*(2)*(3)	(5) Space Heating Emission Factor	(6) Space Heating Emissions (1)*(2)*(5)	(7) Space Cooling Emission Factor	(8) Space Cooling Emissions (1)*(2)*(7)
SF Detached							
SF Attached							
Mult. Family							
Large Commercial							
Med. Commercial							
Small Commercial							
Office-Professional							
Wholesale							
Education							
Other							

TOTAL EMISSIONS   Process ____________ Space Heating ______________ Space Cooling _________________

Industrial ___________ = Total Manufacturing Land Use _________ * Industrial Emission Factor ___________

* Fuel Proportion ___________

ENGLISH

5. Metric Unit Worksheets

Summarized in this section are all metric unit worksheets.

WORKSHEET 1M

INPUT DATA RECORD IN METRIC UNITS

Variable Name	Value/Computation	Inputs to Worksheets	Units
Area of Analysis	___	=	Square Meters
Vacant Developable	___		Square Meters
Vacant Undevelopable	___		Square Meters
Vacant Land	= Vacant Developable ÷ (Area of Analysis - Vacant Undevelopable)	=	*
Median Price	___		$
Median Income	___		$
Land Cost	= Median Price ÷ Median Income	=	*
Collection Capacity	___		Million Gallons Per Day
Peak Flow	___	=	Million Gallons Per Day
% Collection Reserve	= 100* (Collection Capacity - Peak Flow) ÷ Peak Flow	=	*
Manufacturing Workers	___		Employees
Tract Area	___		Square Kilometers
Manufacturing Density	= Manufacturing Workers ÷ Tract Area	=	Employees Per Square Kilometers
Nonmobility	___	=	*
Drivers	___		100s of Drivers
County Area	___		Square Kilometers
Driver Density	= Drivers ÷ County Area	=	100s of Drivers Per Square Kilometer
Sewered Land	___		Square Meters
Sewer Service	= Sewered Land ÷ Area of Analysis	=	*
School Kids	___		Children
Dwelling Units	___		100s of Dwelling Units
Kid Density	= School Kids ÷ Dwelling Units	=	Children Per 100 Dwelling Units
Limited Access	___		Interchanges
Interchanges	= 1,000,000* Limited Access ÷ Area of Analysis	=	Interchanges Per Square Kilometer
Current Employment	= ___		Employees
Future Employment	= ___		Employees
SMSA Area	___		Square Kilometers
Employment Growth	= (Future Employment - Current Employment) ÷ SMSA Area	=	Employees Per Square Kilometer
Track	___		Kilometers
Railroads	= 1,000,000* Track ÷ Area of Analysis	=	Railroad Kilometers Per Square Kilometer Land Area
Zoned Office	= ___		Square Meters

*Unitless

WORKSHEET 1M (CONTINUED)

INPUT DATA RECORD IN METRIC UNITS

Variable Name	Value/Computation	Inputs to Worksheets	Units
Office Zoning	= Zoned Office ÷ Area of Analysis	=	*
House Density	= 100* Dwelling Units ÷ Tract Area		Dwelling Units Per Square Kilometer
Zoned Industrial	________		Square Meters
Industrial Zoning	= Zoned Industrial ÷ Area of Analysis	=	*
Population Growth	________	=	*
Office Vacancy	________	=	*
Airport Distance	________	=	Kilometers
Office Workers	________		Employees
Office Employees	= Office Workers ÷ Tract Area	=	Employees Per Square Kilometer
Future Population	________		People
Employee Ratio	= Future Employment ÷ Future Population	=	*
Unemployment	________	=	*
Future Income	________	=	$
Government	________	=	Millions of $
Collection Reserve	= Collection Capacity - Peak Flow	=	Millon Gallons Per Day
Interceptors	________		Kilometers
Interceptor Density	= 1,000,000* Interceptors ÷ Area of Analysis	=	Kilometers of Interceptor Pipe Per Square Kilometer Land Area
Poverty	________	=	*
Onsite Restrictions	________	=	*
County Growth	________	=	*
Project Cost	________		Thousand $
Federal Funds	________		Thousand $
Index One	________		*
Index Two	________		*
Population Served	________		People

---

*Unitless

WORKSHEET 1M (CONTINUED)

INPUT DATA RECORD IN ENGLISH UNITS

Variable Name	Value/Computation	Inputs to Worksheets	Units
Sewer Costs	= 1,000* ((Project Cost ÷ Index One) - (Federal Funds ÷ Index Two)) ÷ Population Served	=	$ Per Person
Treatment Capacity	____________	=	Million Gallons Per Day
Vacant Houses	____________	=	*
County Interchanges	____________		Interchanges
Interchange Density	= Interchanges ÷ (640* County Interchanges ÷ County Area)	=	*
Zoned Residential	____________		Square Meters
Residential Zoning	= Zoned Residential ÷ Area of Analysis	=	*
Current Income	____________		$
Income Growth	= Future Income-Current Income	=	$
Current Medicals	____________		Employees
Future Medicals	____________		Employees
Hospital Growth	= (Future Medicals - Current Medicals) ÷ Current Medicals	=	*
Current Houses	____________		Dwelling Units
Future Houses	____________		Dwelling Units
Housing Growth	= (Future Houses - Current Houses) ÷ Current Houses	=	*
Restriction Years	____________	=	Years
Phasing	____________	=	*
Transit Stops	____________	=	*
CBD Distance	____________	=	Kilometers

*Unitless

WORKSHEET 2M

LAND USE PROJECTIONS

Residential = (-2.148 * ______ Vacant Land) + (1.321 * ______ Land Cost) + (0.0041 * ______ %Collection Reserve) + (0.0072 * ______ Manufacturing Density)
- (4.646 * ______ Nonmobility) + (0.3117 * ______ Driver Density) + 3.327 = ☐ Dwelling Units Per 10,000 Acres*

Commercial = (987.5 * ______ Sewer Service) - (1036 * ______ Vacant Land) - (6.621 * ______ Kid Density) + (3714 * ______ Interchanges)
- (10.13 * ______ Employment Growth) - (0.6029 * ______ %Collection Reserve) + 1234 = ☐ Square Meters Floor Area Per 10,000 Square Meters

Office-Professional = (102.7 * ______ Railroads) + (7685 * ______ Office Zoning) + (8.424 * ______ Peak Flow) + (0.1981 * ______ House Density)
- (411.0 * ______ Industrial Zoning) + (131.3 * ______ Population Growth) - 105.6 = ☐ Square Meters Floor Area Per 10,000 Square Meters

Manufacturing = (369.6 * ______ Railroads) - (893.0 * ______ Vacant Land) + (1.770 * ______ Manufacturing Density) + (19724 * ______ Office Zoning)
+ (53.87 * ______ Office Vacancy) + (3.239 * ______ Airport Distance) + 140.3 = ☐ Square Meters Floor Area Per 10,000 Square Meters

Wholesale = (98.23 * ______ Driver Density) + (19.80 * ______ Office Vacancy) + (1.985 * ______ Office Employees) + (1387 * ______ Employee Ratio)
+ (1595 * ______ Unemployment) - (0.0244 * ______ Future Income) - 438.7 = ☐ Square Meters Floor Area Per 10,000 Square Meters

Highways = (0.0087 * ______ Railroads) + (0.0091 * ______ Land Cost) - (0.00005 * ______ Government) + (0.0002 * ______ Collection Reserve)
+ (25.94 * ______ Interceptor Density) + 0.0045 = ☐ Lane Kilometers Per 10,000 Square Meters

Education = (-731.3 * ______ Poverty) + (170.0 * ______ Sewer Service) + (100.4 * ______ Land Cost) + (21.85 * ______ Onsite Restrictions)
- (93.02 * ______ County Growth) - (0.3248 * ______ Sewer Costs) + 98.45 = ☐ Square Meters Floor Area Per 10,000 Square Meters

Recreation = (168.1 * ______ Railroads) + (2.631 * ______ Treatment Capacity) + (322.1 * ______ County Growth) + (2.522 * ______ Office Employees)
- (3226 * ______ Vacant Houses) - (557.8 * ______ Industrial Zoning) + 122.9 = ☐ Square Meters Land Use Per 10,000 Square Meters

Other = (161.8 * ______ Railroads) - (0.0693 * ______ Future Income) - (2795 * ______ Vacant Houses) + (150.0 * ______ County Growth)
- (67.81 * ______ Interchange Density) + (92.70 * ______ Residential Zoning) + 708.5 = ☐ Square Meters Floor Area Per 10,000 Square Meters

---

*10,000 Square Meters refers to Area of Analysis

WORKSHEET 3M

FINAL LAND USE PROJECTIONS

(1) Land Use Projections From Worksheet 2M	(2) Disaggregation Percentages	(3) Area of Analysis ÷ By 10,000	(4) Final Land Use Projection (1) * (2) * (3)	(Per Area of Analysis)
Residential	% Single Family		Total Single Family Detached =	Dwelling Units
Residential	% Two Family		Total Single Family Attached =	Dwelling Units
Residential	% Multi Family		Total Multiple Family =	Dwelling Units
Commercial	% Large Commercial[1]		Total Large Commercial =	Square Meters
Commercial	% Medium Commercial[2]		Total Medium Commercial =	Square Meters
Commercial	% Small Commercial[3]		Total Small Commercial =	Square Meters
Office-Professional			Total Office-Professional =	Square Meters
Manufacturing			Total Manufacturing	Square Meters
Wholesale			Total Wholesale =	Square Meters
Education			Total Education =	Square Meters
Other			Total Other =	Square Meters
Recreation			Total Recreation =	Square Meters
Highways			Total Highways =	Lane Kilometers

[1] Large commercial = commercial development with floor area > 9,290 m^2.

[2] Medium commercial = commercial development with floor area between 4,645 and 9,290 m^2.

[3] Small commercial = commercial development with floor area < 4,645 m^2.

METRIC

WORKSHEET 4M (Optional)

DEFAULT DISAGGREGATION EQUATIONS

% Single Family ☐ = 1 ÷ (1 + 92.8 * EXP (-0.0137 * Kid Density ________ - 0.000918 * Income Growth ________ - 0.784 * Sewer Service ________
- 22.7 * Office Zoning ________ + 2.98 * Nonmobility ________ + 0.181 * Hospital Growth ________))

% Multi Family ☐ = (1-% Single Family ________) * (1 ÷ (1 + 1.24* EXP (-438 * Housing Growth ________ + 5.48 * Poverty ________
+ 34.1 * Office Zoning ________ - 0.454 * Railroads ________ - 0.0365 * Peak Flow ________)))

% Two Family ☐ = (1-% Single Family ________ - % Multiple Family ________)

% Large Commercial ☐ = 1 ÷ (1 + 0.104 * EXP (0.215 * Office Vacancy ________ - 0.507 * Onsite Restrictions ________ + 0.0232 * Treatment Capacity ________
- 0.0159 * Kid Density ________ + 0.0603 * Restriction Years ________))

% Medium Commercial ☐ = (1-% Large Commercial ________) * (1 ÷ (1 + 0.585 * EXP (1.54 * Phasing ________ + 0.00459 * Transit Stops ________
+ 0.0111 * CBD Distance ________ + 0.00417 * Government ________ - 1.48 * Vacant Land ________)))

% Small Commercial ☐ = (1-% Large Commercial ________ - % Medium Commercial ________)

Note: EXP is the exponential function. Thus $EXP(X) = e^X$.

WORKSHEET 5M (OPTIONAL)

CONFIDENCE INTERVALS FOR PREDICTED LAND USE

Final Projected Land Use Category ____________________

PREDICTOR VARIABLE

Name

____________________ 1. ____________________
____________________ 2. ____________________
____________________ 3. ____________________
____________________ 4. ____________________
____________________ 5. ____________________
____________________ 6. ____________________
Constant Term 7. 1.0

COMPUTING VARIANCE OF DEPENDENT VARIABLE

① x ① x Covariance ____________ = a. ____________
① x ② x Covariance ____________ = b. ____________
① x ③ x Covariance ____________ = c. ____________
① x ④ x Covariance ____________ = d. ____________
① x ⑤ x Covariance ____________ = e. ____________
① x ⑥ x Covariance ____________ = f. ____________
① x ⑦ x Covariance ____________ = g. ____________
② x ① x Covariance ____________ = h. ____________
② x ② x Covariance ____________ = i. ____________
② x ③ x Covariance ____________ = j. ____________
② x ④ x Covariance ____________ = k. ____________
② x ⑤ x Covariance ____________ = l. ____________
② x ⑥ x Covariance ____________ = m. ____________
② x ⑦ x Covariance ____________ = n. ____________
③ x ① x Covariance ____________ = o. ____________
③ x ② x Covariance ____________ = p. ____________
③ x ③ x Covariance ____________ = q. ____________
③ x ④ x Covariance ____________ = r. ____________
③ x ⑤ x Covariance ____________ = s. ____________
③ x ⑥ x Covariance ____________ = t. ____________
③ x ⑦ x Covariance ____________ = u. ____________
④ x ① x Covariance ____________ = v. ____________
④ x ② x Covariance ____________ = w. ____________
④ x ③ x Covariance ____________ = x. ____________
④ x ④ x Covariance ____________ = y. ____________
④ x ⑤ x Covariance ____________ = z. ____________
④ x ⑥ x Covariance ____________ = aa. ____________
④ x ⑦ x Covariance ____________ = bb. ____________

WORKSHEET 5M (OPTIONAL)

CONFIDENCE INTERVALS FOR PREDICTED LAND USE

COMPUTING VARIANCE OF DEPENDENT VARIABLE

⑤ x ① x Covariance ________ = cc. ________
⑤ x ② x Covariance ________ = dd. ________
⑤ x ③ x Covariance ________ = ee. ________
⑤ x ④ x Covariance ________ = ff. ________
⑤ x ⑤ x Covariance ________ = gg. ________
⑤ x ⑥ x Covariance ________ = hh. ________
⑤ x ⑦ x Covariance ________ = ii. ________
⑥ x ① x Covariance ________ = jj. ________
⑥ x ② x Covariance ________ = kk. ________
⑥ x ③ x Covariance ________ = ll. ________
⑥ x ④ x Covariance ________ = mm. ________
⑥ x ⑤ x Covariance ________ = nn. ________
⑥ x ⑥ x Covariance ________ = oo. ________
⑥ x ⑦ x Covariance ________ = pp. ________
⑦ x ① x Covariance ________ = qq. ________
⑦ x ② x Covariance ________ = rr. ________
⑦ x ③ x Covariance ________ = ss. ________
⑦ x ④ x Covariance ________ = tt. ________
⑦ x ⑤ x Covariance ________ = uu. ________
⑦ x ⑥ x Covariance ________ = vv. ________
⑦ x ⑦ x Covariance ________ = ww. ________
Sum ⓐ through (ww) = 43. ________
Standard Deviation of Dependent Variable = √㊸ 44. ________
t - statistic of predictive equation 46. 1.69
If Final Projected Land Use is Residential or Commercial, set equal to the disaggregation percentage 47. 100
± Confidence Interval = ㊻ x ㊹ x ㊼ ÷ 100 48. ________

WORKSHEET 6M

MOTOR VEHICLE TRIPS

Effective Radius (in km) = $0.000564 * \sqrt{(\text{Area of Analysis, in meters}^2)}$

= ____________________ Kilometers

(1) Total Land Use	(2) Work Trip Rates	(3) Work Trips (1)*(2)	(4) Other Trip Rates	(5) Other Trips (1)*(4)
Single Family Detached				
Single Family Attached				
Multiple Family				

Residential Work Trips __________

Residential Other Trips __________

Large Commercial				
Medium Commercial				
Small Commercial				
Office-Professional				
Manufacturing				
Wholesale				
Education				
Other				
Recreation				

Total Work Trips __________

Total Other Trips __________

---

*See Page 2-26 for a definition of Effective Radius.

WORKSHEET 7M

VEHICLE KILOMETERS TRAVELED (VKT)

Work Trip Length ________ Miles   Other Trip Length ________ Miles   Work Proportion ________ (Default = 0.40)   Other Proportion ________ (Default = 0.40)

VKT^{*}_{IW} ☐ = (Total Work Trips ________ * Work Trip Length ________) - (Residential Work Trips ________ * Work Proportion ________ * Effective Radius ________)

VKT_{AW} ☐ = (Total Work Trips ________ * Effective Radius ________) - (Residential Work Trips ________ * Work Proportion ________ * Effective Radius ________)

VKT_{IO} ☐ = (Total Other Trips ________ * Other Trip Length ________) - (Residential Other Trips ________ * Other Proportion ________ * Effective Radius ________)

VKT_{AO} ☐ = (Total Other Trips ________ * Effective Radius ________) - (Residential Other Trips ________ * Other Proportion ________ * Effective Radius ________)

Peak Hour Proportion ☐ (Default = 0.10)   Off Peak Hour Proportion ☐ (Default = 0.90)

Facility Proportions

	Work	Other
Expressways		
Arterials		
Local Streets		

Average Route Speeds (miles per hour)

Peak		Off Peak	
	(Default = 37)		(Default = 45)
	(Default = 20)		(Default = 28)
	(Default = 15)		(Default = 18)

Trip Sum A ☐ = Manufacturing Work ________ + Manufacturing Other ________ + Wholesale Work ________ + Wholesale Other ________

Trip Sum B ☐ = Total Work Trips ________ + Total Other Trips ________

HD Correction ☐ = (Sum A ÷ Sum B) - 0.05, if less than 0, set equal to 0.

Automobile/Gas Proportion ☐ = 0.804 - HD Correction

Heavy Duty/Gas Proportion ☐ = 0.046 + 0.8 * HD Correction

Heavy Duty/Diesel Proportion ☐ = 0.032 + 0.2 * HD Correction

---

*Subscripts for VMT variables are defined as follows: I = impact area, A = area of analysis, W = work trips, O = other trips.

WORKSHEET 8M

CATEGORIZED VKT

AREA OF ANALYSIS

↓VKT_{AW}↓ ↓VKT_{AO}↓

VKT^*_{APE} ☐ = Peak ______ * (______ * Expressways Work ______ + ______ * Expressways Other ______)

VKT_{APA^*} ☐ = Peak ______ * (______ * Arterials Work ______ + ______ * Arterials Other ______)

VKT_{APL} ☐ = Peak ______ * (______ * Local Work ______ + ______ * Local Other ______)

VKT_{AO^*E} ☐ = Off Peak ______ * (______ * Expressways Work ______ + ______ * Expressways Other ______)

$VKT_{AO^*A^*}$ ☐ = Off Peak ______ * (______ * Arterials Work ______ + ______ * Arterials Other ______)

VKT_{AO^*L} ☐ = Off Peak ______ * (______ * Local Work ______ + ______ * Local Other ______)

IMPACT AREA

↓VKT_{IW}↓ ↓VKT_{IO}↓

VKT_{IPE} ☐ = Peak ______ * (______ * Expressways Work ______ + ______ * Expressways Other ______)

VKT_{IPA^*} ☐ = Peak ______ * (______ * Arterials Work ______ + ______ * Arterials Other ______)

VKT_{IPL} ☐ = Peak ______ * (______ * Local Work ______ + ______ * Local Other ______)

VKT_{IO^*E} ☐ = Off Peak ______ * (______ * Expressways Work ______ + ______ * Expressways Other ______)

$VKT_{IO^*A^*}$ ☐ = Off Peak ______ * (______ * Arterials Work ______ + ______ * Arterials Other ______)

VKT_{IO^*L} ☐ = Off Peak ______ * (______ * Local Work ______ + ______ * Local Work ______)

Subscripts for VMT variables are defined as follows: I = impact area, A = area of analysis, P = peak hour, O - off-peak hour, E = expressways, A* = arterials, L = local streets.

WORKSHEET 9M

MOTOR VEHICLE EMISSION FACTORS

Vehicle Type = ______________ (Automobile Gas, Light Duty Truck Gas, Heavy Duty Gas, or Heavy Duty Diesel)

Pollutant = ______________ (CO, NO_x, or HC)

Region = ______________ (Low alt., High alt., or Calif.)

Speed = ______________ miles per hour

Ambient Temperature = ______________ °F

Year of Impact Assessment (t+10) = ______________

Cold Starts = ________ % Hot Starts = ________ %

(1) Vehicle Age (Years)	(2) Model Year	(3) Base Emission Rate (C_{ipn})	(4)* Hydrocarbon Crankcase/ Evaporate Emission Rate (H_i)	(5) Total Emission Rate (3)+(4)	(6) Fraction of Travel (m_{in})	(7) Speed/Temp./Cold-Hot Starts Correction Factor (r_{ipstwx})	(8) Model Year Total Emissions (5)*(6)*(7)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
≥13							

*Note H_i = 0 for CO and NO_x; for these pollutants, enter the values for C_{ipn} directly in column (5).

Average Emission Factor ______________

WORKSHEET 10M

COMPOSITE MOTOR VEHICLE EMISSION FACTORS

Speed ______________ (miles per hour)

Pollutant ______________ (CO, NO_x, HC, SO_x or Particulates)

Vehicle Class	(1) Average Emission Factor	(2) Vehicle Class Proportion	(3) Product (1)*(2)
Automobile/Gas			
Light Duty Truck/Gas		0.118	
Heavy Duty/Gas			
Heavy Duty/Diesel			

Composite Emission Factor __________

TOTAL MOTOR VEHICLE EMISSIONS

Pollutant ____________________

Condition	(1) Average Speed	(2) VKT Data	(3) Emission Factors	(4) Total Emissions (2)*(3)
Peak, Expressways		VKT_{APE}		
Peak, Arterials		VKT_{APA}		
Peak, Local Streets		VKT_{APL}		
Off Peak, Expressways		VKT_{AOE}		
Off Peak, Arterials		VKT_{AOA}		
Off Peak, Local Streets		VKT_{AOL}		
			Sum	
			*	0.365
Area of Analysis, Total Motor Vehicle Emissions			=	
			(in kilograms/year)	
Peak, Expressways		VKT_{IPE}		
Peak, Arterials		VKT_{IPA}		
Peak, Local Streets		VKT_{IPL}		
Off Peak, Expressways		VKT_{IOE}		
Off Peak, Arterials		VKT_{IOA}		
Off Peak, Local Streets		VKT_{IOL}		
			Sum	
			*	0.365
Impact Area, Total Motor Vehicle Emissions			=	
			(in kilograms/year)	

WORKSHEET 12M

STATIONARY SOURCE EMISSIONS

Fuel Type ____________ (Gas, Oil, or Electricity)   Pollutant __________ (CO, HC, NO_x, SO_x, Particulates, or Kwh)

(1) Total Land Use	(2) Fuel Proportion	(3) Process Emission Factor	(4) Process Emissions (1)*(2)*(3)	(5) Space Heating Emission Factor	(6) Space Heating Emissions (1)*(2)*(5)	(7) Space Cooling Emission Factor	(8) Space Cooling Emissions (1)*(2)*(7)
SF Detached							
SF Attached							
Mult. Family							
Large Commercial							
Med. Commercial							
Small Commercial							
Office-Professional							
Wholesale							
Education							
Other							

TOTAL EMISSIONS   Process __________ Space Heating __________ Space Cooling __________

Industrial __________ = Total Manufacturing Land Use ________ * Industrial Emission Factor ________

* Fuel Proportion ________

WORKSHEET 13M

EMISSIONS SUMMARY

Total Emissions	CO	HC	NO_x	SO_x	Particulates	Kilowatt-Hours
(1) Process						
(2) Space Heating						
(3) Space Cooling						
(4) Industrial						
(5) Total Stationary Source Emissions (1)+(2)+(3)+(4)						
(6) Area of Analysis, Total Motor Vehicle Emissions						
(7) Total Emissions Area of Analysis (5)+(6)						
(8) Electric Utility Emission Factors						
(9) Total Kilowatt-Hours						
(10) Electric Utility Emissions (8)*(9)						
(11) Impact Area, Total Motor Vehicle Emissions						
(12) Total Emissions, Impact Area (5)+(10)+(11)						

6. Example on Using Worksheets

This section presents an example of the use of the computation worksheets, in English units. One example of each worksheet is filled out, even though in an actual application, several copies of some of the worksheets would be required. The data used in this example were collected from case study #1, Willimantic, CT.

WORKSHEET 1

INPUT DATA RECORD IN ENGLISH UNITS

Variable Name	Value/Computation	Inputs To Worksheets	Units
Area of Analysis	6456	= 6456	Acres
Vacant Developable	4537		Acres
Vacant Undevelopable	603		Acres
Vacant Land	= Vacant Developable ÷ (Area of Analysis - Vacant Undevelopable)	= 0.775	*
Median Price	$3,500		$
Median Income	$5,893		$
Land Cost	= Median Price ÷ Median Income	= 0.594	*
Collection Capacity	15.3		Million Gallons Per Day
Peak Flow	9.0	= 9.0	Million Gallons Per Day
% Collection Reserve	= 100* (Collection Capacity - Peak Flow) ÷ Peak Flow	= 70	
Manufacturing Workers	28		Employees
Tract Area	= 4.5		Square Miles
Manufacturing Density	= Manufacturing Workers ÷ Tract Area	= 622.2	Employees Per Square Mile
Nonmobility	0.572	= 0.572	*
Drivers	202		100s of Drivers
County Area	514		Square Miles
Driver Density	= Drivers ÷ County Area	= 0.393	100s of Drivers Per Square Mile
Sewered Land	3685		Acres
Sewer Service	= Sewered Land ÷ Area of Analysis	= 0.571	*
School Kids	39		Children
Dwelling Units	46		100s of Dwelling Units
Kid Density	= Schools Kids ÷ Dwelling Units	= 85	Children Per 100 Dwelling Units
Limited Access	0		Interchanges
Interchanges	= 640* Limited Access ÷ Area of Analysis	= 0	Interchanges Per Square Mile
Current Employment	280		Employees
Future Employment	348		Employees
SMSA Area	514		Square Miles
Employment Growth	= (Future Employment - Current Employment) ÷ SMSA Area	= 13.23	Employees Per Square Mile
Track	2.5		Miles
Railroads	= 640* Track ÷ Area of Analysis	= 0.248	Railroad Miles Per Square Mile Land Area
Zoned Office	142		Acres

---

*Unitless

WORKSHEET 1 (CONTINUED)

INPUT DATA RECORD IN ENGLISH UNITS

Variable Name	Value/Computation		Inputs to Worksheets	Units
Office Zoning	= Zoned Office : Area of Analysis	=	0.022	*
House Density	= 100* Dwelling Units ÷ Tract Area	=	1022	Dwelling Units Per Square Mile
Zoned Industrial	770			Acres
Industrial Zoning	= Zoned Industrial ÷ Area of Analysis	=	0.1193	*
Population Growth	0.223	=	0.223	*
Office Vacancy	0.2	=	0.2	*
Airport Distance	22.1	=	22.1	Miles
Office Workers	4			Employees
Office Employees	= Office Workers ÷ Tract Area	=	88.89	Employees Per Square Mile
Future Population	845			People
Employee Ratio	= Future Employment ÷ Future Population	=	0.4118	*
Unemployment	0.075	=	0.075	*
Future Income	$ 10 067		$ 10 067	$
Government	10.9		10.9	Millions of $
Collection Reserve	= Collection Capacity - Peak Flow	=	6.3	Million Gallons Per Day
Interceptors	1.2			Miles
Interceptor Density	= 640* Interceptors ÷ Area of Analysis	=	0.1190	Miles of Interceptor Pipe Per Square Mile Land Area
Poverty	0.128	=	0.128	*
Onsite Restrictions	2	=	2	*
County Growth	0.223	=	0.223	*
Project Cost	690			Thousand $
Federal Funds	207			Thousand $
Index One	101.6			*
Index Two	96.5			*
Population Served	16 973			People

*Unitless

WORKSHEET 1 (CONTINUED)

INPUT DATA RECORD IN ENGLISH UNITS

Variable Name	Value/Computation	Inputs to Worksheets	Units
Sewer Costs	= 1,000* ((Project Cost ÷ Index One) - (Federal Funds ÷ Index Two)) ÷ Population Served	= $27.374	$ Per Person
Treatment Capacity	2.2	= 2.2	Million Gallons Per Day
Vacant Houses	0.025	= 0.025	*
County Interchanges	21		Interchanges
Interchange Density	= Interchanges ÷ (640* County Interchanges ÷ County Area)	= 0	*
Zoned Residential	1681		Acres
Residential Zoning	= Zoned Residential ÷ Area of Analysis	= 0.2604	*
Current Income	$5,893		$
Income Growth	= Future Income - Current Income	= $4,174	$
Current Medicals	6		Employees
Future Medicals	10		Employees
Hospital Growth	= (Future Medicals - Current Medicals) ÷ Current Medicals	= 0.667	*
Current Houses	72		Dwelling Units
Future Houses	276		Dwelling Units
Housing Growth	= (Future Houses - Current Houses) ÷ Current Houses	= 2.833	*
Restriction Years	3	= 3	Years
Phasing	0	= 0	*
Transit Stops	0	= 0	*
CBD Distance	2.3	= 2.3	Miles

*Unitless

WORKSHEET 2

LAND USE PROJECTIONS

Residential = (-8692 * 0.775 Vacant Land) + (5347 * 0.594 Land Cost) + (16.42 * 70 % Collection Reserve) + (11.24 * 622.2 Manufacturing Density)
- (18804 * 0.572 Nonmobility) + (487.2 * 0.393 Driver Density) + 13466 = **7484** Dwelling Units Per 10,000 Acres*

Commercial = (4302 * 0.571 Sewer Service) - (4515 * 0.775 Vacant Land) - (28.84 * 85 Kid Density) + (6249 * 0 Interchanges)
- (17.04 * 13.23 Employment Growth) - (2.626 * 70 %Collection Reserve) + 5376 = **1473** 1,000 Square Feet Per 10,000 Acres

Office-Professional = (719.5 * 0.248 Railroads) + (33478 * 0.022 Office Zoning) + (36.70 * 9.0 Peak Flow) + (0.3324 * 1022 House Density)
- (1791 * 0.1193 Industrial Zoning) + (572.0 * 0.223 Population Growth) - 459.3 = **1039** 1,000 Square Feet Per 10,000 Acres

Manufacturing = (2591 * 0.248 Railroads) - (3890 * 0.775 Vacant Land) + (2.978 * 622.2 Manufacturing Density) + (85923 * 0.022 Office Zoning)
+ (234.7 * 0.2 Office Vacancy) + (22.7 * 22.1 Airport Distance) + 611.2 = **2531** 1,000 Square Feet Per 10,000 Acres

Wholesale = (166.5 * 0.393 Driver Density) + (86.28 * 0.2 Office Vacancy) + (3.340 * 88.89 Office Employees) + (6043 * 0.4118 Employee Ratio)
+ (6949 * 0.075 Unemployment) - (0.1065 * 10067 Future Income) - 1911 = **448** 1,000 Square Feet Per 10,000 Acres

Highways = (35.22 * 0.248 Railroads) + (22.98 * 0.594 Land Cost) - (0.1167 10.9 Government) + (0.5379 * 6.3 Collection Reserve)
+ (25.94 * 0.1190 Interceptor Density) + 11.35 = **38.9** Miles Per 10,000 Acres

Education = (-3.186 * 0.128 Poverty) + (723.0 * 0.571 Sewer Service) + (437.5 * 0.594 Land Cost) + (95.17 * 2 On-Site Restrictions)
- 405.2 * 0.223 County Growth) - (1.415 * 27.374 Sewer Costs) + 428.9 = **1162** 1,000 Square Feet Per 10,000 Acres

Recreation = (270.4 * 0.248 Railroads) + (2.631 * 2.2 Treatment Capacity) + (322.1 * 0.223 County Growth) + (0.9742 * 0.2 Office Employees)
- (1226 * 0.025 Vacant Houses) - (557.8 * 0.1193 Industrial Zoning) + 59.52 = **57.2** Acres Per 10,000 Acres

Other = (1134 * 0.248 Railroads) - (0.3020 * 10067 Future Income) - (12175 * 0.025 Vacant Houses) + (649.0 * 0.223 County Growth)
- (245.4 * 0 Interchange Density) + (403.3 * 0.2604 Residential Zoning) + 3087 = **273** 1,000 Square Feet Per 10,000 Acres

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*10,000 Acres refers to Area of Analysis

WORKSHEET 3

FINAL LAND USE PROJECTIONS

(1) Land Use Projections From Worksheet 2		(2) Disaggregation Percentages		(3) Area of Analysis ÷ By 10,000	(4) Final Land Use Projection (1) * (2) * (3)		
Residential	7484	% Single Family	.398	.6456	Total Single Family Detached =	1923	Dwelling Units
Residential	7484	% Two Family	0	.6456	Total Single Family Attached =	0	Dwelling Units
Residential	7484	% Multi Family	.602	.6456	Total Multiple Family =	2909	Dwelling Units
Commercial	1473	% Large Commercial	.987	.6456	Total Large Commercial =	939	1,000 Square Feet
Commercial	1473	% Medium Commercial	.011	.6456	Total Medium Commercial =	10.5	1,000 Square Feet
Commercial	1473	% Small Medium	.002	.6456	Total Small Commercial =	1.90	1,000 Square Feet
Office-Professional	1039			.6456	Total Office-Professional =	671	1,000 Square Feet
Manufacturing	2531			.6456	Total Manufacturing =	1634	1,000 Square Feet
Wholesale	448			.6456	Total Wholesale =	289	1,000 Square Feet
Education	1162			.6456	Total Education =	750	1,000 Square Feet
Other	273			.6456	Total Other =	176	1,000 Square Feet
Recreation	57.2			.6456	Total Recreation =	36.9	Acres
Highways	38.9			.6456	Total Highways =	25.1	Miles

ENGLISH

WORKSHEET 4 (Optional)

DEFAULT DISAGGREGATION EQUATIONS

% Single Family **0.398** = 1 ÷ (1 + 92.8 * EXP (-0.0137 * Kid Density 85 - 0.000918 * Income Growth 4174 - 0.784 * Sewer Service 0.571
- 22.7 * Office Zoning 0.022 + 2.98 * Nonmobility 0.572 + 0.181 * Hospital Growth 0.667))

% Multi Family **0.602** = (1-% Single Family 0.398) * (1 ÷ (1 + 1.24* EXP (-438 * Housing Growth 2.833 + 5.48 * Poverty 0.128
+ 34.1 * Office Zoning 0.022 - 0.732 * Railroads 0.248 - 0.0365 * Peak Flow 9.0)))

% Two Family **0** = (1-% Single Family 0.398 - % Multiple Family 0.602)

% Large Commercial **0.987** = 1 ÷ (1 + 0.104 * EXP (0.215 * Office Vacancy 0.2 - 0.507 * Onsite Restrictions 2 + 0.0232 * Treatment Capacity 2.2
- 0.0159 * Kid Density 85 + 0.0603 * Restriction Years 3))

% Medium Commercial **0.011** = (1-% Large Commercial 0.987) * (1 ÷ (1 + 0.585 * EXP (1.54 * Phasing 0 + 0.00459 * Transit Stops 0
+ 0.0173 * CBD Distance 2.3 + 0.00417 * Government 10.9 - 1.48 * Vacant Land 0.775)))

% Small Commercial **0.002** = (1-% Large Commercial 0.987 - % Medium Commercial 0.011)

Note: EXP is the exponential function. Thus $EXP(X) = e^{x}$.

WORKSHEET 5 (OPTIONAL)

CONFIDENCE INTERVALS FOR PREDICTED LAND USE

Final Projected Land Use Category Total Single Family Detached

PREDICTOR VARIABLE

Name	
Vacant Land = VACANT	1. 0.775
Land Cost = LAND	2. 0.594
% Collection Reserve = RECAP1	3. 70.0
Manu. Density = MANJOB	4. 622.2
Nonmobility = STAY	5. 0.572
Driver Density = DRIVE	6. 0.393
Constant Term	7. 1.0

COMPUTING VARIANCE OF DEPENDENT VARIABLE

Predictor Variables		Covariance Term from Appendix A		Multiplier			Resultant
① x ①	x	.716 E7	x	1.0	=	a.	4,300,475
① x ②	x	-.262 E6	x	2.0	=	b	- 241,223
① x ③	x	.892 E2	x	2.0	=	c.	9,678
① x ④	x	.203 E4	x	2.0	=	d.	1,957,752
① x ⑤	x	-.253 E7	x	2.0	=	e.	-2,243,098
① x ⑥	x	.219 E6	x	2.0	=	f.	133,404
① x ⑦	x	-.388 E7	x	2.0	=	g.	-6,014,000
② x ②	x	.109 E7	x	1.0	=	h.	384,591
② x ③	x	.102 E4	x	2.0	=	i.	84,823
② x ④	x	-.467 E2	x	2.0	=	j.	- 34,519
② x ⑤	x	-.189 E6	x	2.0	=	k.	- 128,432
② x ⑥	x	-.522 E5	x	2.0	=	k!	- 24,371

($\Sigma_a^{k'}$ = -1,814,920)

Predictor Variables		Covariance Term from Appendix A		Multiplier		Resultant
② x ⑦	x	−.423 E6	x	2.0	=	l. − 502,524
③ x ③	x	.147 E2	x	1.0	=	m. 72,030
③ x ④	x	−.119 E1	x	2.0	=	n. − 103,659
③ x ⑤	x	.548 E4	x	2.0	=	o. 438,838
③ x ⑥	x	−.113 E3	x	2.0	=	p. − 6,217
③ x ⑦	x	−.529 E4	x	2.0	=	q. − 740,600
④ x ④	x	.118 E2	x	1.0	=	r. 4,568,168
④ x ⑤	x	−.139 E5	x	2.0	=	s. −9,893,976
④ x ⑥	x	.327 E2	x	2.0	=	t. 15,992
④ x ⑦	x	.280 E4	x	2.0	=	u. 3,484,320
⑤ x ⑤	x	.437 E8	x	1.0	=	v. 14,297,941
⑤ x ⑥	x	−.222 E6	x	2.0	=	w. − 99,809
⑤ x ⑦	x	−.158 E8	x	2.0	=	x. −18,075,200
⑥ x ⑥	x	.464 E5	x	1.0	=	y. 7,166
⑥ x ⑦	x	−.713 E5	x	2.0	=	z. − 56,041
⑦ x ⑦	x	.105 E8	x	1.0	=	aa. 10,500,000

Sum ⓐ through ⓐⓐ : 8. 2,091,509

Standard Deviation of Dependent Variable = $\sqrt{⑧}$: 9. 1,446

Disaggregation proportion: 10. 0.398

(This is 1.0 for all land uses except residential and commercial. The proportion is the decimal equivalent of % Single Family, etc. The numbers come from Col. 2 of Worksheet 3.)

Confidence Interval (±) = ⑨ x ⑩ x 1.69 : 11. ± 980.7

WORKSHEET 6

MOTOR VEHICLE TRIPS

Effective Radius*= (0.0004973* Area of Analysis 6,456 $)^{1/2}$

= 1.79 Miles

(1) Total Land Use		(2) Work Trip Rates	(3) Work Trips (1)*(2)	(4) Other Trip Rates	(5) Other Trips (1)*(4)
Single Family Detached	1923	1.8	2461	9.0	17 307
Single Family Attached	0	1.5	0	7.0	0
Multiple Family	2909	1.0	2909	5.0	14 545

Residential Work Trips 5370

Residential Other Trips 31852

Large Commercial	939	0	0	40	37 560
Medium Commercial	10.5	0	0	64	672
Small Commercial	1.90	0	0	67	127
Office-Professional	671	16	10,736	0	0
Manufacturing	1634	5.0	8,170	0	0
Wholesale	289	4.0	1,156	0	0
Education	750	0	0	4.0	3000
Other	176	0.13	23	5.0	880
Recreation	36.9	0	0	42	1550

Total Work Trips 25 455

Total Other Trips 75 641

---

*See Page 2-26 for a definition of Effective Radius.

WORKSHEET 7

VEHICLE MILES TRAVELED (VMT)

Work Trip Length 6.86 Miles   Other Trip Length 6.01 Miles   Work Proportion 0.40 (Default = 0.40)   Other Proportion 0.40 (Default = 0.40)

VMT^*_{IW} 170776 = (Total Work Trips 25455 * Work Trip Length 6.86) - (Residential Work Trips 5370 * Work Proportion 0.4 * Effective Radius 1.79)

VMT_{AW} 41720 = (Total Work Trips 25455 * Effective Radius 1.79) - (Residential Work Trips 5370 * Work Proportion 0.4 * Effective Radius 1.79)

VMT_{IO} 431 796 = (Total Other Trips 75641 * Other Trip Length 6.01) - (Residential Other Trips 31852 * Other Proportion 0.4 * Effective Radius 1.79)

VMT_{AO} 112 591 = (Total Other Trips 75641 * Effective Radius 1.79) - (Residential Other Trips 31852 * Other Proportion 0.4 * Effective Radius 1.79)

Peak Hour Proportion 0.10 (Default = 0.10)   Off Peak Hour Proportion 0.90 (Default = 0.90)

Facility Proportions

	Work	Other
Expressways	0.15	0.10
Arterials	0.21	0.21
Local Streets	0.13	0.20

Average Route Speeds (miles per hour)

Peak		Off Peak	
37	(Default = 37)	45	(Default = 45)
20	(Default = 20)	30	(Default = 28)
15	(Default = 15)	18	(Default = 18)

Trip Sum A 9326 = Manufacturing Work 8170 + Manufacturing Other 0 + Wholesale Work 1156 + Wholesale Other 0

Trip Sum B 101096 = Total Work Trips 25455 + Total Other Trips 75641

HD Correction 0.042 = (Sum A ÷ Sum B) - 0.05, if less than 0, set equal to 0.

Automobile/Gas Proportion 0.762 = 0.804 - HD Correction

Heavy Duty/Gas Proportion 0.080 = 0.046 + 0.8 * HD Correction

Heavy Duty/Diesel Proportion 0.040 = 0.032 + 0.2 * HD Correction

---

*Subscripts for VMT variables are defined as follows: I = impact area, A = area of analysis, W = work trips, O = other trips.

WORKSHEET 8

CATEGORIZED VMT

AREA OF ANALYSIS

$\downarrow VMT_{AW}\downarrow$ $\downarrow VMT_{AO}\downarrow$

VMT^{*}_{APE} **1752** = Peak 0.1 * (41 720 * Expressways Work 0.15 + 112591 * Expressways Other 0.10)

VMT_{APA} **3241** = Peak 0.1 * (41 720 * Arterials Work 0.21 + 112591 * Arterials Other 0.21)

VMT_{APL} **2794** = Peak 0.1 * (41 720 * Local Work 0.13 + 112591 * Local Other 0.20)

$VMT_{A\dot{O}E}$ **15765** = Off Peak 0.9 * (41 720 * Expressways Work 0.15 + 112591 * Expressways Other 0.10)

$VMT_{A\dot{O}A}$ **29 165** = Off Peak 0.9 * (41 720 * Arterials Work 0.21 + 112591 * Arterials Other 0.21)

$VMT_{A\dot{O}L}$ **25 148** = Off Peak 0.9 * (41 720 * Local Work 0.13 + 112591 * Local Other 0.20)

IMPACT AREA

$\downarrow VMT_{IW}\downarrow$ $\downarrow VMT_{IO}\downarrow$

VMT_{IPE} **6 880** = Peak 0.1 * (170 776 * Expressways Work 0.15 + 431 796 * Expressways Other 0.10)

VMT_{IPA} **12654** = Peak 0.1 * (170 776 * Arterials Work 0.21 + 431796 * Arterials Other 0.21)

VMT_{IPL} **70856** = Peak 0.1 * (170 776 * Local Work 0.13 + 431796 * Local Other 0.20)

$VMT_{I\dot{O}E}$ **61916** = Off Peak 0.9 * (170 776 * Expressways Work 0.15 + 431796 * Expressways Other 0.10)

$VMT_{I\dot{O}A}$ **113 886** = Off Peak 0.9 * (170 776 * Arterials Work 0.21 + 431796 * Arterials Other 0.21)

$VMT_{I\dot{O}L}$ **97704** = Off Peak 0.9 * (170 776 * Local Work 0.13 + 431796 * Local Work 0.20)

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*Subscripts for VMT variables are defined as follows: I = impact area, A = area of analysis, P = peak hour, $\dot{O}$ = off-peak hour, E = expressways, A = arterials, L = local streets.

WORKSHEET 9

MOTOR VEHICLE EMISSION FACTORS

Vehicle Type = Auto Gas (Automobile Gas, Light Duty Truck Gas, Heavy Duty Gas, or Heavy Duty Diesel)

Pollutant = CO (CO, NO_x, or HC)

Speed = 30 miles per hour

Year of Impact Assessment (t+10) = 1990

Region = Low Alt (Low alt., High alt., or Calif.)

Ambient Temperature = 75 °F

Cold Starts = 20 %

Hot Starts = 27 %

(1) Vehicle Age (Years)	(2) Model Year	(3) Base Emission Rate (C_{ipn})	(4)* Hydrocarbon Crankcase/ Evapcrate Emission Rate (H_i)	(5) Total Emission Rate (3)+(4)	(6) Fraction of Travel (m_{in})	(7) Speed/Temp./Cold-Hot Starts Correction Factor (r_{ipstwx})	(8) Model Year Total Emissions (5)*(6)*(7)
1	1990	2.8	0	2.8	0.081	0.63	0.143
2	1989	3.1	0	3.1	0.110	0.63	0.215
3	1988	3.4	0	3.4	0.107	0.63	0.229
4	1987	3.6	0	3.6	0.106	0.63	0.240
5	1986	3.9	0	3.9	0.102	0.63	0.251
6	1985	4.2	0	4.2	0.096	0.63	0.254
7	1984	4.5	0	4.5	0.088	0.63	0.249
8	1983	4.8	0	4.8	0.077	0.63	0.233
9	1982	5.0	0	5.0	0.064	0.63	0.202
10	1981	5.3	0	5.3	0.049	0.63	0.164
11	1980	5.6	0	5.6	0.033	0.63	0.116
12	1979	5.6	0	5.6	0.023	0.63	0.081
≥13	1978	5.6	0	5.6	0.064	0.63	0.226

Average Emission Factor 2.60

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*Note H_i = 0 for CO and NO_x; for these pollutants, enter the values for C_{ipn} directly in column (5).

WORKSHEET 10

COMPOSITE MOTOR VEHICLE EMISSION FACTORS

Speed 30 (miles per hour)

Pollutant CO (CO, NO_x, HC, SO_x or Particulates)

Vehicle Class	(1) Average Emission Factor	(2) Vehicle Class Proportion	(3) Product (1)*(2)
Automobile/Gas	2.60	0.762	1.98
Light Duty Truck/Gas	9.80	0.118	1.16
Heavy Duty/Gas	117	0.080	9.36
Heavy Duty/Diesel	28.7	0.040	1.15

Composite Emission Factor 13.7

TOTAL MOTOR VEHICLE EMISSIONS

Pollutant CO

Condition	(1) Average Speed	(2) VMT Data	(3) Emission Factors	(4) Total Emissions (2)*(3)
Peak, Expressways	37	VMT_{APE} 1752	8.13	14 244
Peak, Arterials	20	VMT_{APA} 3241	16.2	52504
Peak, Local Streets	15	VMT_{APL} 2794	21.2	59 233
Off Peak, Expressways	45	VMT_{AOE} 15765	6.64	104 680
Off Peak, Arterials	30	VMT_{AOA} 29165	13.7	399 561
Off Peak, Local Streets	18	VMT_{AOL} 25148	17.9	450 149
			Sum	1 080 371
			*	0.805
Area of Analysis, Total Motor Vehicle Emissions			=	869 699
			(in pounds/year)	
Peak, Expressways	37	VMT_{IPE} 6 880	8.13	55934
Peak, Arterials	20	VMT_{IPA} 12654	16.2	204 995
Peak, Local Streets	15	VMT_{IPL} 10856	21.2	230 147
Off Peak, Expressways	45	VMT_{IOE} 61916	6.64	411 122
Off Peak, Arterials	30	VMT_{IOA} 113 886	13.7	1560238
Off Peak, Local Streets	18	VMT_{IOL} 97704	17.9	1748 902
			Sum	4 211 338
			*	0.805
Impact Area, Total Motor Vehicle Emissions			=	3 390 127
			(in pounds/year)	

WORKSHEET 12

STATIONARY SOURCE EMISSIONS

Fuel Type Oil (Gas, Oil, or Electricity) Pollutant CO (CO, HC, NO_x, SO_x, Particulates, or Kwh)

(1) Total Land Use	(2) Fuel Proportion	(3) Process Emission Factor	(4) Process Emissions (1)*(2)*(3)	(5) Space Heating Emission Factor	(6) Space Heating Emissions (1)*(2)*(5)	(7) Space Cooling Emission Factor	(8) Space Cooling Emissions (1)*(2)*(7)
SF Detached 1923	0.6	1.2	1385	6.27	7234	0	0
SF Attached 0	0.6	1.2	0	6.27	0	0	0
Mult. Family 2909	0.6	1.0	1745	3.25	5673	0.11	192
Large Commercial 939	0.6	0.09	51	1.65	930	0	0
Med. Commercial 10.5	0.6	0.09	1	1.65	10	0	0
Small Commercial 1.90	0.6	0.09	0.1	1.65	2	0	0
Office-Professional 671	0.6	0	0	1.65	664	0.12	48
Wholesale 289	0.6	0.09	16	1.65	286	0	0
Education 750	0.6	0	0	1.20	540	0.04	18
Other 176	0.6	0	0	1.43	151	0.04	4

TOTAL EMISSIONS Process 3198 Space Heating 15490 Space Cooling 262

Industrial 14706 = Total Manufacturing Land Use 1634 * Industrial Emission Factor 15

* Fuel Proportion 0.6

WORKSHEET 13

EMISSIONS SUMMARY

Total Emissions	CO	HC	NO_x	SO_x	Particulates	Kilowatt-Hours
(1) Process	3198					
(2) Space Heating	15490					
(3) Space Cooling	262					
(4) Industrial	14 706					
(5) Total Stationary Source Emissions (1)+(2)+(3)+(4)	33 656					1.98×10^8
(6) Area of Analysis, Total Motor Vehicle Emissions	869 699					
(7) Total Emissions Area of Analysis (5)+(6)	903 355 pounds/year					
(8) Electric Utility Emission Factors	2.38×10^{-4}					
(9) Total Kilowatt-Hours	1.98×10^8					
(10) Electric Utility Emissions (8)*(9)	47 124					
(11) Impact Area, Total Motor Vehicle Emissions	3 390 127					
(12) Total Emissions, Impact Area (5)+(10)+(11)	3 470 907 pounds/year					

III. REFERENCES

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APPENDIX A

COMPLETE STATISTICAL OUTPUT
OF THE PREDICTIVE EQUATIONS

Covariance data for the following Final Projected Land Use categories can be found on the indicated page:

Final Projected Land Use Category	Page
Single Family Detached	A-2
Single Family Attached	A-2
Multiple Family	A-2
Large Commercial	A-4
Medium Commercial	A-4
Small Commercial	A-4
Office-Professional	A-6
Manufacturing	A-8
Wholesale	A-10
Education	A-14
Other	A-18
Recreation	A-16
Highways	A-12

1. RES Equation

```
EQUATION  1
***********

SMPL VECTOR
   1  40

ORDINARY LEAST SQUARES

VARIABLES...

          RES
          VACANT
          LAND
          RECAP1
          MANJOB
          STAY
          DRIVE
          C

MEAN OF DEPENDENT VARIABLE IS  8713.5469

INDEPENDENT        ESTIMATED            STANDARD                 T-               MEAN OF
 VARIABLE          COEFFICIENT          ERROR                STATISTIC            VARIABLE

 VACANT         -8691.57422          2675.66455            -3.24837875           0.60694695

 LAND            5347.30078          1041.82104             5.13264751           0.53672218

 RECAP1            16.4241486           3.83258915          4.28539181         181.299988

 MANJOB            11.2375050           3.43206120          3.27427197         204.263763

 STAY          -18803.8398           6609.87891            -2.84480762           0.44994849

 DRIVE            487.237305           215.450577           2.26148033           1.72454357

 C              13466.2617           3235.08081             4.16257286           1.00000000

   R-SQUARED =  0.7416

   DURBIN-WATSON STATISTIC (ADJ. FOR  0 GAPS) =  2.0923

   NUMBER OF OBSERVATIONS =   40

   SUM OF SQUARED RESIDUALS =          .356145E+09

   STANDARD ERROR OF THE REGRESSION =            3285.16

   ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS
            VACANT      LAND       RECAPI      MANJOB       STAY        DRIVE     (CONSTANT)
    VACANT 0.716E+07 -0.262E+06  0.892E+02  0.203E+04 -0.253E+07  0.219E+06 -0.388E+07
    LAND  -0.262E+06  0.109E+07  0.102E+04 -0.467E+02 -0.189E+06 -0.522E+05 -0.423E+06
    RECAP1 0.892E+02  0.102E+04  0.147E+02 -0.119E+01  0.548E+04 -0.113E+03 -0.529E+04
    MANJOB 0.203E+04 -0.467E+02 -0.119E+01  0.118E+02 -0.139E+05  0.327E+02  0.280E+04
    STAY  -0.253E+07 -0.189E+06  0.548E+04 -0.139E+05  0.437E+08 -0.222E+06 -0.158E+08
    DRIVE  0.219E+06 -0.522E+05 -0.113E+03  0.327E+02 -0.222E+06  0.464E+05 -0.713E+05
(CONSTANT)-0.388E+07 -0.423E+06 -0.529E+04  0.280E+04 -0.158E+08 -0.713E+05  0.105E+08
```

```
    LINE    3          PRINCETON UNIVERSITY               *   TSP   *          VERSION OF AUGUST, 1969            PAGE     6





                                     PLOT OF ACTUAL(*) AND FITTED(+) VALUES                    PLOT OF RESIDUALS(0)


ID     ACTUAL       FITTED                                                        RESIDUAL
                                                                                                       0.0
   1    8209.        7484.                  **                                      725.          .     .0   .
   2    2782.       -12.56     *    *                                               .279E+04      .     .    0
   3    8223.        .1046E+05               *   *                                 -.224E+04      .0    .    .
   4    5911.        5511.              **                                          400.          .     0    .
   5    6920.        .1249E+05             *        *                              -.557E+04 0    .     .    .
   6    6257.        7808.                *  *                                     -.155E+04      .  0  .    .
   7    .2891E+05    .2351E+05                                         *        *   .540E+04      .     .    .    0
   8    9706.        6300.                *    *                                    .341E+04      .     .    .0
   9    .1197E+05    .1512E+05                     *     *                         -.315E+04      0     .    .
  10    5868.        .1155E+05           *         *                               -.568E+04 0    .     .    .
  11    .2357E+05    .1731E+05                              *          *            .625E+04      .     .    .     0
  12    9987.        9811.                      *                                   176.          .     0    .
  13    .1926E+05    .1978E+05                                  **                 -525.          .    0.    .
  14    7094.        4616.             *   *                                        .248E+04      .     .   0.
  15    6072.        6941.               * *                                       -869.          .   0 .    .
  16    3745.        7860.           *      *                                      -.412E+04    0 .     .    .
  17    9709.        9520.                     *                                    189.          .     0    .
  18    .1517E+05    8073.                   *           *                          .709E+04      .     .    .       0
  19    5100.        8030.              *    *                                     -.293E+04      0     .    .
  20    7540.        6669.                * *                                       871.          .     .0   .
  21    6771.        5563.              * *                                         .119E+04      .     . 0  .
  22    5017.        2994.          *   *                                           .202E+04      .     .  0 .
  23    7372.        4533.             *    *                                       .284E+04      .     .    0
  24    .1894E+05    .1769E+05                               * *                    .125E+04      .     . 0  .
  25    5903.        1451.       *       *                                          .445E+04      .     .    .  0
  26    582.0        1457.      **                                                 -875.          .   0 .    .
  27    6515.        5900.               **                                         615.          .     .0   .
  28    4626.        5867.             * *                                         -.124E+04      .  0  .    .
  29    6550.        8455.                *  *                                     -.191E+04      . 0   .    .
  30    .1498E+05    .1556E+05                          **                         -579.          .    0.    .
  31    7772.        4634.             *    *                                       .314E+04      .     .    .0
  32    2112.        5402.         *    *                                          -.329E+04     0.     .    .
  33    6516.        6753.                *                                        -237.          .    0.    .
  34    .1358E+05    .1382E+05                        *                            -243.          .    0.    .
  35    .1050E+05    .1235E+05                   *  *                              -.184E+04      . 0   .    .
  36    369.0        3770.      *    *                                             -.340E+04     0.     .    .
  37    .1322E+05    .1145E+05                    *  *                              .177E+04      .     .  0 .
  38    6313.        7227.                **                                       -914.          .   0 .    .
  39    5375.        6790.              *  *                                       -.141E+04      .  0  .    .
  40    1539.        6018.           *       *                                     -.448E+04   0  .     .    .
```

2. <u>COMM Equation</u>

```
EQUATION  2
***********

SMPL VECTOR
   1  40

ORDINARY LEAST SQUARES

VARIABLES...

      COMM
      SERVED
      VACANT
      KIDS
      ACCESS
      JOBCHG
      RECAP1
      C

MEAN OF DEPENDENT VARIABLE IS  1848.5686

INDEPENDENT        ESTIMATED          STANDARD                T-              MEAN OF
 VARIABLE          COEFFICIENT         ERROR              STATISTIC          VARIABLE

SERVED            4301.81250        1002.06228            4.29287338        0.60547256

VACANT           -4514.91016        1133.73901           -3.98231792        0.60694695

KIDS               -28.8412018        11.1874228         -2.57800198       99.0000000

ACCESS            6248.92187        2225.56396            2.80779171        0.09044975

JOBCHG             -17.0374908         7.56761169        -2.25136948       36.6831866

RECAP1              -2.62619495        1.75866604        -1.49328709      181.299988

C                 5375.52344        1415.94165            3.79642963        1.00000000

   R-SQUARED =  0.5734

   DURBIN-WATSON STATISTIC (ADJ. FOR  0 GAPS) =  2.1636

   NUMBER OF OBSERVATIONS =   40

   SUM OF SQUARED RESIDUALS =          .749141E+06

   STANDARD ERROR OF THE REGRESSION =          1506.69

   ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS
          SERVED      VACANT      KIDS        ACCESS      JOBCHG      RECAP1     (CONSTANT)
  SERVED 0.100E+07 -0.295E+04 -0.211E+04 -0.225E+06 -0.183E+04 -0.568E+03 -0.207E+06
  VACANT-0.295E+04  0.129E+07  0.177E+04 -0.862E+05  0.121E+04  0.145E+03 -0.102E+07
    KIDS-0.211E+04  0.177E+04  0.125E+03 -0.731E+04 -0.332E+01  0.804E+00 -0.115E+05
  ACCESS-0.225E+06 -0.862E+05 -0.731E+04  0.495E+07 -0.435E+04 -0.326E+03  0.683E+06
  JOBCHG-0.183E+04  0.121E+04 -0.332E+01 -0.435E+04  0.573E+02  0.177E+01 -0.133E+04
  RECAP1-0.568E+03  0.145E+03  0.804E+00 -0.326E+03  0.177E+01  0.309E+01 -0.420E+03
(CONSTANT)-0.207E+06 -0.102E+07 -0.115E+05  0.683E+06 -0.133E+04 -0.420E+03  0.200E+07
```

```
    LINE    4          PRINCETON UNIVERSITY               *   TSP   *          VERSION OF AUGUST, 1969            PAGE    9


                                     PLOT OF ACTUAL(*) AND FITTED(+) VALUES                    PLOT OF RESIDUALS(0)

ID     ACTUAL       FITTED                                                        RESIDUAL
                                                                                                     0.0
   1    1419.         1472.               +                                        -53.3          .   0    .
   2    419.4        -1478.    +      *                                             .190E+04       .   .    .0
   3    879.1         1162.             *+                                         -283.          .   0    .
   4    892.4         890.9             +                                           1.51          .   0    .
   5    1474.         1901.               * +                                      -428.          .  0.    .
   6    2778.         2632.                    +                                    146.          .   .0   .
   7    2959.         2488.                   + *                                   471.          .   . 0  .
   8    1794.         2340.                 * +                                    -546.          .  0.    .
   9    1206.         775.5             +*                                          430.          .   . 0  .
  10    388.8         744.9           * +                                          -356.          .  0.    .
  11    3862.         1936.                 +       *                               .193E+04       .   .    .0
  12    2470.         1693.                +  *                                   777.          .   .  0 .
  13    2971.         3948.                     *   +                              -978.          .0  .    .
  14    2154.         1559.                + *                                    596.          .   . 0  .
  15    1118.         651.9            + *                                        466.          .   . 0  .
  16    1104.         2505.              *    +                                  -.140E+04      0   .    .
  17    2027.         1035.              +  *                                     992.          .   .   0.
  18    8732.         5986.                                 +         *             .275E+04       .   .    .   0
  19    701.9         3724.            *           +                             -.302E+04 0    .   .    .
  20    2776.         3446.                    *  +                                -670.          . 0 .    .
  21    1462.         2373.               *   +                                  -911.          . 0 .    .
  22    1897.         83.45          +      *                                     .181E+04       .   .    .0
  23    1640.         1464.               +*                                      176.          .   .0   .
  24    2771.         1812.                 +  *                                  958.          .   .  0 .
  25    774.0         1888.             *   +                                    -.111E+04      .0  .    .
  26    145.4         95.07          +                                             50.3          .   .0   .
  27    729.8        -823.1       +    *                                            .155E+04       .   .    0
  28    722.8         1904.            *    +                                    -.118E+04      .0  .    .
  29    174.2         754.0          *  +                                        -580.          .  0.    .
  30    2234.         3674.                  *     +                             -.144E+04      0   .    .
  31    1197.         2772.              *     +                                 -.157E+04      0   .    .
  32    171.6        -207.9         +*                                             380.          .   . 0  .
  33    807.6         2012.             *   +                                    -.120E+04      .0  .    .
  34    1071.         1971.              *  +                                    -900.          . 0 .    .
  35    .1127E+05     6667.                                   +                 *   .466E+04       .   .    .         0
  36    245.7        -286.2         + *                                            532.          .   . 0  .
  37    1510.         2443.               *   +                                  -933.          . 0 .    .
  38    1875.         3317.                 *    +                               -.144E+04      0   .    .
  39    609.2         800.9            *+                                        -192.          .   0    .
  40    511.5         1880.            *    +                                    -.137E+04      0   .    .
```

3. **OFFICE Equation**

```
EQUATION  3
***********

SMPL VECTOR
   1  40

ORDINARY LEAST SQUARES

VARIABLES...

     OFFICE
     RRMILE
     OZONED
     PEAK
     DUACRE
     IZONED
     POPDIF
     C

MEAN OF DEPENDENT VARIABLE IS   503.1760

INDEPENDENT        ESTIMATED             STANDARD               T-             MEAN OF
 VARIABLE          COEFFICIENT           ERROR               STATISTIC         VARIABLE

RRMILE              719.511719           137.541382          5.23123741        0.46907347

OZONED            33478.0352            6491.85156           5.15693092        0.00529748

PEAK                 36.6961060           10.2877779         3.56696129        5.88499546

DUACRE                0.33335096           0.10663390        3.12612534      692.524902

IZONED            -1790.61548            772.712891         -2.31730938        0.06514716

POPDIF              572.025391           271.222656          2.10906124        0.20634961

C                  -459.871338           147.449326         -3.11884308        1.00000000

  R-SQUARED =  0.7017

  DURBIN-WATSON STATISTIC (ADJ. FOR  0 GAPS) =  2.1360

  NUMBER OF OBSERVATIONS =   40

  SUM OF SQUARED RESIDUALS =          .293272E+07

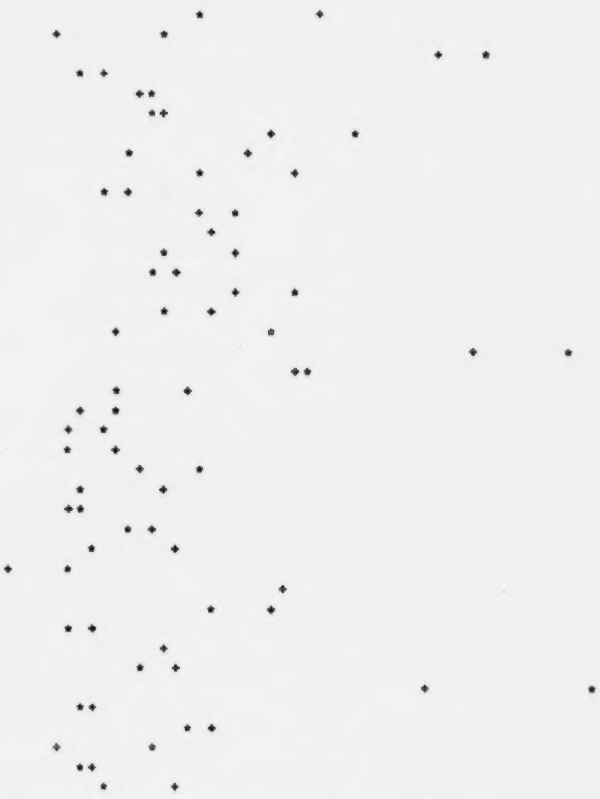
  STANDARD ERROR OF THE REGRESSION =          298.111

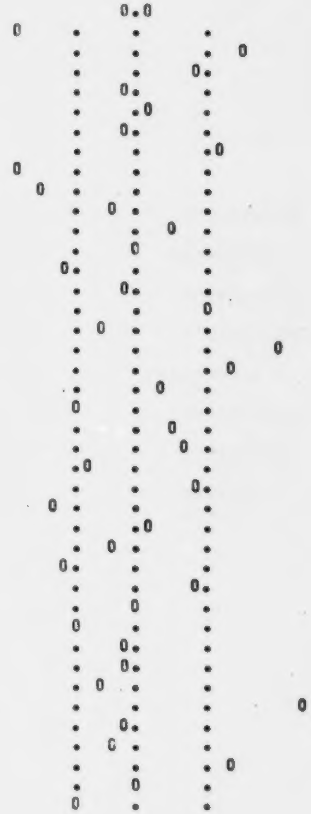
  ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS
         RRMILE      OZONED      PEAK       DUACRE      IZONED      POPDIF    (CONSTANT)
RRMILE  0.169E+05  0.196E+06  0.148E+03 -0.364E+01 -0.401E+05  0.182E+04 -0.603E+04
OZONED  0.196E+06  0.421E+08 -0.903E+04 -0.316E+02 -0.184E+07  0.267E+06 -0.175E+06
PEAK    0.148E+03 -0.903E+04  0.106E+03  0.682E-01 -0.131E+04  0.170E+03 -0.642E+03
DUACRE -0.364E+01 -0.316E+02  0.682E-01  0.114E-01  0.150E+02  0.925E+01 -0.928E+01


IZONED -0.401E+05 -0.184E+07 -0.131E+04  0.150E+02  0.597E+06 -0.157E+05 -0.979E+04
POPDIF  0.182E+04  0.267E+06  0.170E+03  0.925E+01 -0.157E+05  0.736E+05 -0.238E+05
(CONSTANT)-0.603E+04 -0.175E+06 -0.642E+03 -0.928E+01 -0.979E+04 -0.238E+05  0.217E+05
```

```
                                      PLOT OF ACTUAL(*) AND FITTED(+) VALUES          PLOT OF RESIDUALS(0)

   ID      ACTUAL       FITTED                                              RESIDUAL
                                                                                              0.0
    1      552.7        1046.                                                -493.
    2      411.8       -23.02                                                 435.
    3      1687.        1474.                                                 212.
    4      86.40        168.3                                                -81.9
    5      337.3        298.5                                                 38.8
    6      339.7        404.3                                                -64.6
    7      1169.        855.9                                                 313.
    8      288.5        759.1                                                -471.
    9      555.1        939.3                                                -384.
   10      147.9        261.7                                                -114.
   11      687.5        553.9                                                 134.
   12      589.3        609.6                                                -20.3
   13      390.4        711.8                                                -321.
   14      382.4        451.1                                                -68.7
   15      935.9        673.5                                                 262.
   16      403.4        578.3                                                -175.
   17      822.3        234.2                                                 588.
   18      1999.        1626.                                                 373.
   19      995.9        923.7                                                 72.2
   20      230.9        479.9                                                -249.
   21      199.0        64.30                                                 135.
   22      177.8        18.59                                                 159.
   23      34.00        215.1                                                -181.
   24      567.3        325.3                                                 242.
   25      94.70        428.6                                                -334.
   26      65.10        50.92                                                 14.2
   27      251.9        345.6                                                -93.7
   28      144.6        441.4                                                -297.
   29      40.60       -208.6                                                 249.
   30      887.5        896.8                                                -9.34
   31      577.2        645.7                                                -269.
   32      33.90        115.5                                                -81.6
   33      385.5        419.8                                                -34.3
   34      296.6        431.2                                                -135.
   35      2111.        1446.                                                 666.
   36      94.60        132.6                                                -38.0
   37      489.7        581.4                                                -91.7
   38      380.1       -19.17                                                 399.
   39      98.60        122.3                                                -23.7
   40      185.2        447.5                                                -262.
```





A-7

4. **MANF Equation**

```
EQUATION  4
***********

SMPL VECTOR
   1  40

ORDINARY LEAST SQUARES

VARIABLES...

     MANF
     RRMILE
     VACANT
     MANJOB
     OZONED
     VACOFF
     AIRPRT
     C

MEAN OF DEPENDENT VARIABLE IS  1805.8608

INDEPENDENT         ESTIMATED            STANDARD                  T-                MEAN OF
 VARIABLE          COEFFICIENT            ERROR                STATISTIC            VARIABLE

RRMILE             2590.97559           697.218994             3.71615696          0.46907347

VACANT            -3890.12744          1287.65332             -3.02109814          0.60694695

MANJOB                2.97811413           1.40833187           2.11463928        204.263763

OZONED            85922.3750          33632.6289               2.55473232          0.00529748

VACOFF              234.675339            93.9596558           2.49761772          3.16749668

AIRPRT               22.7014465           12.8864851           1.76164722         23.5024567

C                   611.240967          1068.74121              0.57192606          1.00000000

R-SQUARED =  0.6301

DURBIN-WATSON STATISTIC (ADJ. FOR  0 GAPS) =  2.4249

NUMBER OF OBSERVATIONS =   40

SUM OF SQUARED RESIDUALS =          .850977E+08

STANDARD ERROR OF THE REGRESSION =          1605.84

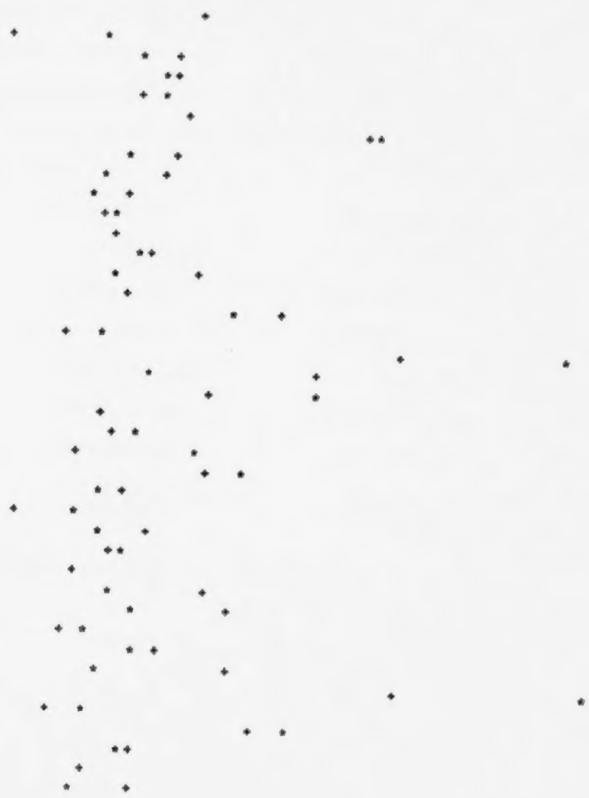
ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS
          RRMILE      VACANT      MANJOB      OZONED      VACOFF      AIRPRT    (CONSTANT)
RRMILE  0.486E+06   0.169E+06  -0.112E+03   0.213E+07  -0.938E+04  -0.267E+03  -0.283E+06
VACANT  0.169E+06   0.166E+07   0.433E+03  -0.171E+07   0.660E+04  -0.475E+04  -0.107E+07
MANJOB -0.112E+03   0.433E+03   0.198E+01  -0.111E+05   0.159E+02  -0.332E+01  -0.529E+03
OZONED  0.213E+07  -0.171E+07  -0.111E+05   0.113E+10   0.743E+06   0.498E+05  -0.721E+07


VACOFF -0.938E+04   0.660E+04   0.159E+02   0.743E+06   0.683E+04   0.168E+03  -0.387E+05
AIRPRT -0.267E+03  -0.475E+04  -0.332E+01   0.498E+05   0.168E+03   0.166E+03  -0.101E+04
CONSTANT -0.283E+06  -0.107E+07  -0.529E+03  -0.721E+07  -0.387E+05  -0.101E+04   0.114E+07
```

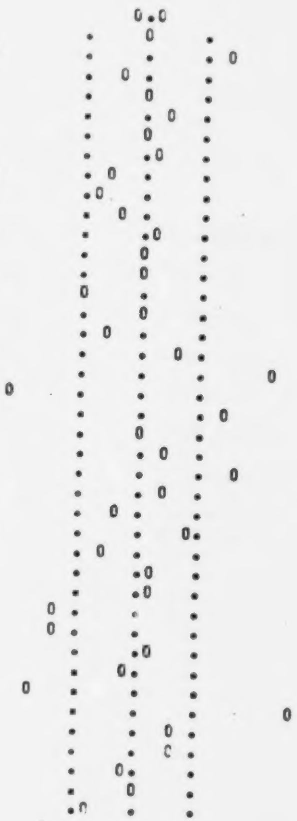
```
ID    ACTUAL       FITTED

 1    2339.        2531.
 2    491.4       -1520.      -192.
 3    1209.        1916.       .201E+04
 4    1785.        1873.      -707.
 5    1831.        1251.      -88.2
 6    2092.        2193.       580.
 7    6213.        5900.      -101.
 8    1050.        2057.       313.
 9    514.2        1673.      -.101E+04
10    267.7        976.5      -.116E+04
11    736.8        525.2      -709.
12    672.7        820.9       212.
13    1208.        1392.      -148.
14    745.8        2427.      -183.
15    1071.        965.0      -.168E+04
16    3265.        4082.       106.
17    553.4       -328.2      -817.
18    .1011E+05    6711.       882.
19    1426.        4850.       .340E+04
20    4859.        2799.      -.342E+04
21    388.4        534.4       .206E+04
22    1271.        836.1      -146.
23    2365.       -28.29       435.
24    3406.        2770.       .239E+04
25    359.2        874.7       635.
26    60.80       -1274.      -515.
27    428.8        1426.       .133E+04
28    1044.        706.7      -597.
29    83.50       -53.64       338.
30    621.6        2733.       137.
31    1154.        3302.      -.211E+04
32    124.8       -163.1      -.215E+04
33    1311.        1791.       288.
34    517.7        3249.      -480.
35    .1066E+05    6709.      -.273E+04
36    335.5       -571.9       .395E+04
37    4542.        3644.       907.
38    930.2        1154.       998.
39    140.8        174.8      -224.
40    47.40        1328.      -34.0
                              -.128E+04
```

PLOT OF ACTUAL(*) AND FITTED(+) VALUES



PLOT OF RESIDUALS(O)



5. **WHOLE Equation**

```
EQUATION  5
***********

SMPL VECTOR
   1  40

ORDINARY LEAST SQUARES

VARIABLES...

      WHOLE
      DRIVE
      VACOFF
      OFFJOB
      EMPOP
      UNEMP
      PERCAP
      C

 MEAN OF DEPENDENT VARIABLE IS   477.0664

INDEPENDENT          ESTIMATED            STANDARD                  T-                 MEAN OF
 VARIABLE            COEFFICIENT          ERROR                     STATISTIC          VARIABLE

DRIVE               166.454239           20.7087250               8.03787899          1.72454357

VACOFF               86.2756805          19.9433136               4.32604504          3.16749668

OFFJOB                3.34034920          0.97810185              3.41513348         75.1841431

EMPOP              6042.78906          1535.17920                 3.93621063          0.37607706

UNEMP              6948.57422          2431.63574                 2.85757160          0.04894974

PERCAP               -0.10651082          0.04552276             -2.33972645       9726.22266

C                 -1911.15161           668.882324               -2.85723114          1.00000000

  R-SQUARED =  0.7597

  DURBIN-WATSON STATISTIC (ADJ. FOR  0 GAPS) =  2.2514

  NUMBER OF OBSERVATIONS =   40

  SUM OF SQUARED RESIDUALS =          .335096E+07

  STANDARD ERROR OF THE REGRESSION =          318.660

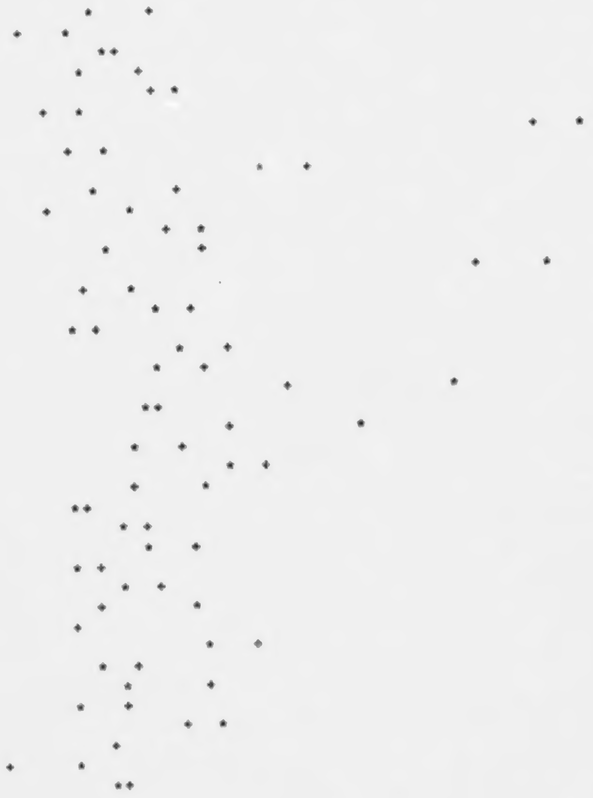
  ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS
          DRIVE       VACOFF      OFFJOB      EMPOP       UNEMP       PERCAP     (CONSTANT)
DRIVE   0.429E+03   0.629E+02   0.685E+00  -0.709E+02   0.735E+04  -0.209E+00   0.709E+03
VACOFF  0.629E+02   0.398E+03   0.434E+01  -0.414E+04  -0.195E+05   0.394E-01   0.434E+03
OFFJOB  0.685E+00   0.434E+01   0.957E+00   0.226E+03  -0.324E+03   0.118E-01  -0.270E+03
EMPOP  -0.709E+02  -0.414E+04   0.226E+03   0.236E+07   0.111E+07  -0.240E+02  -0.711E+06

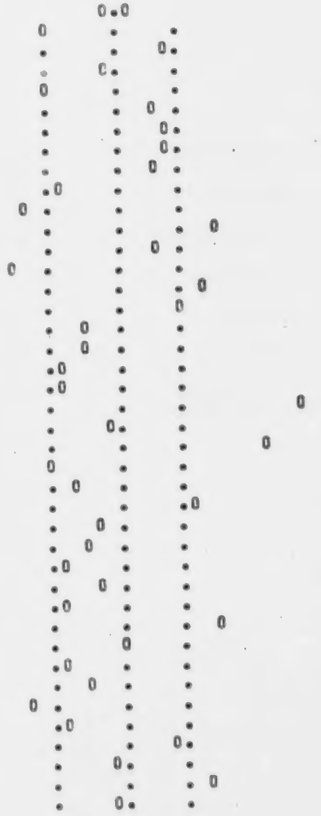

UNEMP   0.735E+04  -0.195E+05  -0.324E+03   0.111E+07   0.591E+07   0.152E+02  -0.780E+06
PERCAP -0.209E+00   0.394E-01   0.118E-01  -0.240E+02   0.152E+02   0.207E-02  -0.125E+02
(CONSTANT) 0.709E+03 0.434E+03 -0.270E+03  -0.711E+06  -0.780E+06  -0.125E+02   0.447E+06
```

```
LINE    7        PRINCETON UNIVERSITY          *  TSP  *       VERSION OF AUGUST, 1969        PAGE   18

                          PLOT OF ACTUAL(*) AND FITTED(+) VALUES                    PLOT OF RESIDUALS(0)

                                                                         RESIDUAL
 ID     ACTUAL      FITTED
  1     114.2       405.8                                                -292.
  2     21.20      -215.0                                                 236.
  3     189.3       233.9                                                -44.6
  4     74.30       368.5                                                -294.
  5     558.1       413.9                                                 144.
  6     88.30      -109.7                                                 198.
  7     2535.       2322.                                                 213.
  8     182.3       28.37                                                 154.
  9     937.6       1171.                                                -233.
 10     133.3       545.6                                                -412.
 11     312.5      -96.10                                                 409.
 12     667.8       504.3                                                 164.
 13     205.0       643.8                                                -439.
 14     2364.       1993.                                                 371.
 15     333.7       59.36                                                 274.
 16     432.9       587.0                                                -154.
 17     .0          138.5                                                -139.
 18     551.5       797.1                                                -246.
 19     425.0       669.4                                                -244.
 20     1871.       1095.                                                 776.
 21     346.8       402.6                                                -55.8
 22     1399.       778.1                                                 620.
 23     300.6       568.6                                                -268.
 24     760.6       966.8                                                -206.
 25     646.0       303.9                                                 342.
 26     14.50       85.42                                                -70.9
 27     218.3       372.6                                                -154.
 28     361.4       597.9                                                -236.
 29     20.50       119.0                                                -58.5
 30     228.4       449.5                                                -221.
 31     570.4       145.6                                                 425.
 32     27.40      -5.900                                                 33.3
 33     671.0       907.3                                                -236.
 34     156.5       305.3                                                -149.
 35     256.5       643.6                                                -387.
 36     5.300       264.0                                                -255.
 37     732.1       531.5                                                 201.
 38     175.0       194.4                                                -19.4
 39     10.90      -340.2                                                 351.
 40     161.1       237.5                                                -56.4
```





6. **HIWAYS Equation**

```
EQUATION  6
***********

SMPL VECTOR
   1  40

ORDINARY LEAST SQUARES

VARIABLES...

     HIWAYS
     RRMILE
     LAND
     GOVT
     RECAP
     CROSS
     C

MEAN OF DEPENDENT VARIABLE IS     43.3924

INDEPENDENT          ESTIMATED            STANDARD              T-                 MEAN OF
 VARIABLE            COEFFICIENT          ERROR              STATISTIC            VARIABLE

RRMILE               35.2186584           9.71726036         3.62434006           0.46907347

LAND                 22.9822540           7.10037518         3.23676586           0.53672218

GOVT                 -0.11664993          0.04293521        -2.71688175          71.3199310

RECAP                 0.53785098          0.23814219         2.25852776          10.2899714

CROSS                25.9384308          16.6402893          1.55877209           0.23038459

C                    11.3462658           8.29916477         1.36715698           1.00000000

R-SQUARED =  0.5226

DURBIN-WATSON STATISTIC (ADJ. FOR  0 GAPS) =  2.1316

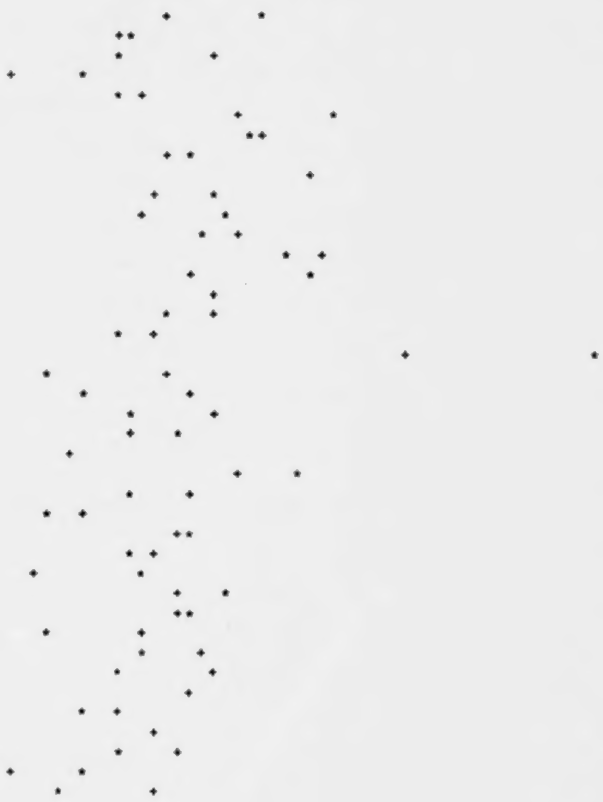
NUMBER OF OBSERVATIONS =   40

SUM OF SQUARED RESIDUALS =          18421.3

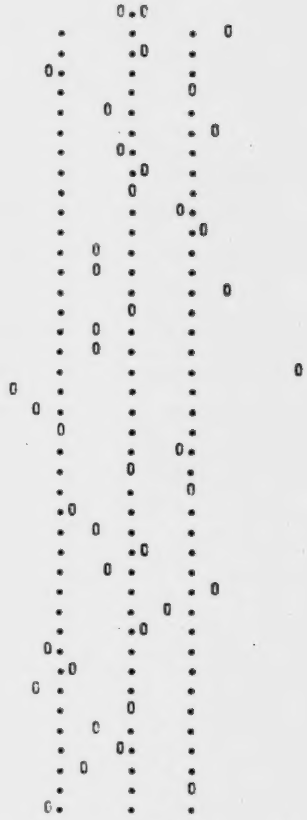
STANDARD ERROR OF THE REGRESSION =          23.2767

ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS
             RRMILE      LAND         GOVT         RECAP        CROSS       (CONSTANT)
RRMILE     0.944E+02  -0.163E+01  -0.966E-02  -0.552E-01  -0.205E+02  -0.374E+02
LAND      -0.163E+01   0.504E+02  -0.633E-01   0.348E-01  -0.889E+01  -0.201E+02
GOVT      -0.966E-02  -0.633E-01   0.184E-02   0.141E-04   0.655E-02  -0.946E-01
RECAP     -0.552E-01   0.348E-01   0.141E-04   0.567E-01   0.593E+00  -0.714E+00
CROSS     -0.205E+02  -0.889E+01   0.655E-02   0.593E+00   0.277E+03  -0.560E+02
(CONSTANT)-0.374E+02  -0.201E+02  -0.946E-01  -0.714E+00  -0.560E+02   0.689E+02
```

PLOT OF ACTUAL(*) AND FITTED(+) VALUES



PLOT OF RESIDUALS(O)



```
ID     ACTUAL      FITTED     RESIDUAL

 1     70.90       38.94        32.0
 2     30.10       25.83        4.27
 3     26.80       55.48       -28.7
 4     15.40      -6.095        21.5
 5     26.70       33.03       -6.33
 6     92.20       62.04        30.2
 7     66.60       68.37       -1.57
 8     47.00       41.85        5.15
 9     84.00       82.59        1.01
10     55.00       36.26        18.7
11     57.50       32.46        25.0
12     52.10       61.43       -9.33
13     75.60       87.82       -12.2
14     83.50       49.46        34.0
15     56.60       53.88        2.72
16     42.30       54.73       -12.4
17     25.30       37.48       -12.2
18     170.0       111.9        58.1
19     3.000       42.40       -39.4
20     15.20       46.81       -31.6
21     31.40       53.30       -21.9
22     45.60       28.40        17.2
23     13.40       12.03        1.37
24     80.20       60.59        19.6
25     30.30       48.84       -18.5
26     4.100       16.45       -12.3
27     48.90       43.69        5.21
28     30.80       38.57       -7.77
29     32.90       2.831        30.1
30     58.50       43.85        14.7
31     48.30       43.07        5.23
32     5.300       32.49       -27.2
33     34.50       52.55       -18.0
34     24.80       54.74       -29.9
35     48.20       48.59       -.395
36     14.00       25.59       -11.6
37     36.50       37.54       -1.04
38     27.70       42.84       -15.1
39     15.90      -4.924        20.8
40     8.400       37.61       -29.2
```

7. EDUC Equation

```
EQUATION  7
***********

SMPL VECTOR
   1  40

ORDINARY LEAST SQUARES

VARIABLES...

      EDUC
      POOR
      SERVED
      LAND
      LIMITS
      PERCHG
      COST
      C

 MEAN OF DEPENDENT VARIABLE IS    662.7139

INDEPENDENT          ESTIMATED              STANDARD                   T-              MEAN OF
 VARIABLE            COEFFICIENT            ERROR                   STATISTIC          VARIABLE

POOR               -3185.58545            670.197266              -4.75320530         0.15904957

SERVED               722.979492           144.078339               5.01796055         0.60547256

LAND                 437.526123            83.0681152              5.26707649         0.53672218

LIMITS                95.1653137           30.2513428              3.14582062         2.47499943

PERCHG              -405.201416           180.390137              -2.24625015         0.25504965

COST                  -1.41497135           0.77642828            -1.82241058        45.4195862

C                    428.885010           168.597427               2.54384041         1.00000000

  R-SQUARED =  0.7545

  DURBIN-WATSON STATISTIC (ADJ. FOR  0 GAPS) =  2.0024

  NUMBER OF OBSERVATIONS =   40

  SUM OF SQUARED RESIDUALS =           .192734E+07

  STANDARD ERROR OF THE REGRESSION =          241.669

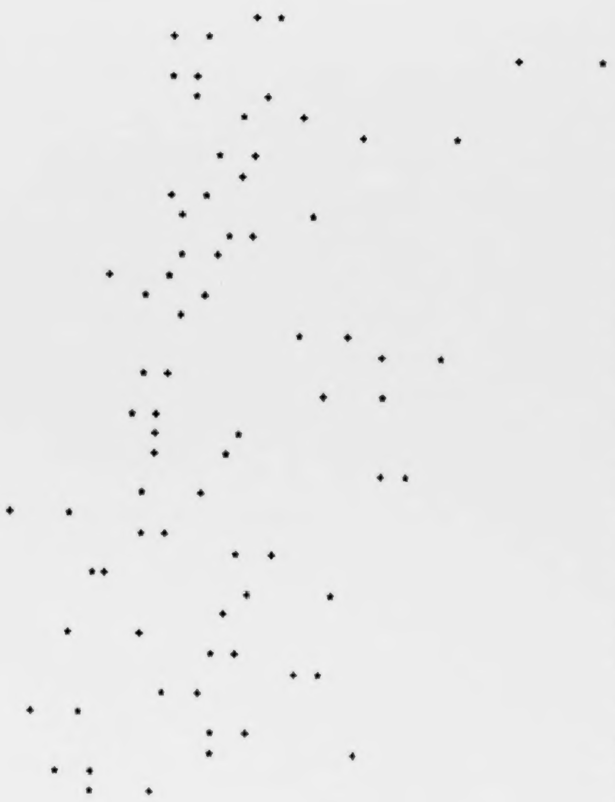
  ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS
     POOR        SERVED      LAND       LIMITS      PERCHG      COST       (CONSTANT)
POOR   0.449E+06  0.153E+05  0.556E+04 -0.349E+04  0.153E+05 -0.178E+03 -0.709E+05
SERVED 0.153E+05  0.208E+05 -0.933E+03 -0.108E+03 -0.371E+04 -0.717E+01 -0.130E+05
LAND   0.556E+04 -0.933E+03  0.690E+04  0.645E+03  0.138E+04 -0.254E+02 -0.482E+04
LIMITS-0.349E+04 -0.108E+03  0.645E+03  0.915E+03 -0.618E+03  0.227E+01 -0.194E+04

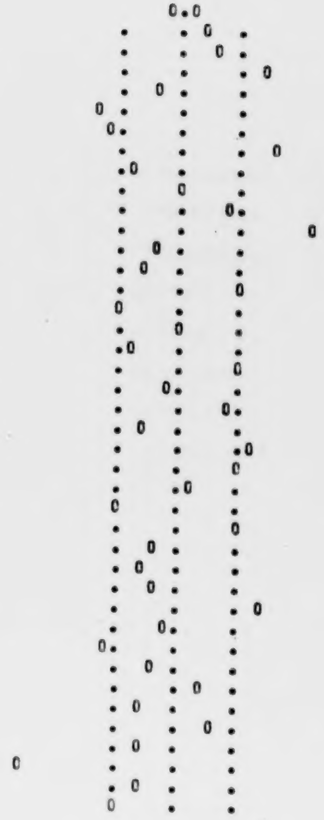

PERCHG 0.153E+05 -0.371E+04  0.138E+04 -0.618E+03  0.325E+05 -0.388E+02 -0.593E+04
COST  -0.178E+03 -0.717E+01 -0.254E+02  0.227E+01 -0.388E+02  0.603E+00  0.232E+02
(CONSTANT)-0.709E+05 -0.130E+05 -0.482E+04 -0.194E+04 -0.593E+04  0.232E+02  0.284E+05
```

```
                                   PLOT OF ACTUAL(*) AND FITTED(+) VALUES        PLOT OF RESIDUALS(0)

 ID    ACTUAL       FITTED                                              RESIDUAL

  1    866.0        751.0                                                 115.
  2    563.4        443.0                                                 120.
  3    2135.        1805.                                                 329.
  4    454.0        529.0                                                -75.0
  5    524.9        816.1                                                -291.
  6    709.5        965.0                                                -255.
  7    1554.        1194.                                                 359.
  8    635.8        787.6                                                -152.
  9    724.0        725.6                                                -1.65
 10    603.9        425.9                                                 178.
 11    984.8        485.5                                                 499.
 12    667.8        760.6                                                -92.8
 13    483.3        615.8                                                -132.
 14    447.4        214.9                                                 233.
 15    350.8        576.0                                                -225.
 16    499.5        505.3                                                -5.75
 17    982.5        1155.                                                -172.
 18    1517.        1283.                                                 233.
 19    368.6        424.3                                                -55.7
 20    1275.        1075.                                                 204.
 21    286.9        415.5                                                -129.
 22    707.3        411.5                                                 296.
 23    655.0        407.2                                                 248.
 24    1374.        1311.                                                 63.0
 25    359.2        580.5                                                -221.
 26    69.70       -168.1                                                 238.
 27    346.0        434.0                                                -88.0
 28    715.5        843.0                                                -127.
 29    147.4        230.3                                                -82.9
 30    1106.        780.4                                                 325.
 31    662.5        700.5                                                -38.0
 32    81.10        329.3                                                -248.
 33    643.7        723.7                                                -80.0
 34    1037.        956.4                                                 80.1
 35    457.6        582.1                                                -125.
 36    95.50       -50.90                                                 146.
 37    615.5        764.7                                                -149.
 38    607.9        1186.                                                -578.
 39    11.60        140.1                                                -128.
 40    160.1        374.7                                                -214.
```





8. REC Equation

```
EQUATION  8
***********

SMPL VECTOR
   1  40

ORDINARY LEAST SQUARES

VARIABLES...

     REC
     RRMILE
     CAPAC2
     PERCHG
     OFFJOB
     VACHSE
     IZONED
     C

MEAN OF DEPENDENT VARIABLE IS   207.8000

INDEPENDENT          ESTIMATED            STANDARD                 T-               MEAN OF
 VARIABLE            COEFFICIENT          ERROR                STATISTIC            VARIABLE

RRMILE              270.401123           56.2478333           4.80731583           0.46907347

CAPAC2                2.63108635          1.06722641          2.46534920          10.8374815

PERCHG              322.055176           91.3438721           3.52574444           0.25504965

OFFJOB                0.97423780          0.35317051          2.75854778          75.1841431

VACHSE            -3225.57251          1262.37156           -2.55516815           0.03909981

IZONED             -557.780029          294.032471           -1.89700127           0.06514716

C                    59.5172882           71.8569489          0.82827461           1.00000000

  R-SQUARED =  0.6471

  DURBIN-WATSON STATISTIC (ADJ. FOR  0 GAPS) =  1.7751

  NUMBER OF OBSERVATIONS =   40

  SUM OF SQUARED RESIDUALS =          498049.

  STANDARD ERROR OF THE REGRESSION =          122.851

  ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS
        RRMILE      CAPAC2     PERCHG      OFFJOB     VACHSE      IZONED     (CONSTANT)
RRMILE  0.316E+04  0.105E+01  0.628E+03 -0.475E+01  0.143E+05 -0.521E+04 -0.152E+04
CAPAC2  0.105E+01  0.114E+01 -0.390E+01 -0.970E-02  0.128E+03 -0.266E+02 -0.144E+02
PERCHG  0.628E+03 -0.390E+01  0.834E+04  0.741E+01 -0.982E+04 -0.277E+04 -0.237E+04
OFFJOB -0.475E+01 -0.970E-02  0.741E+01  0.125E+00 -0.643E+02  0.229E+02 -0.791E+01

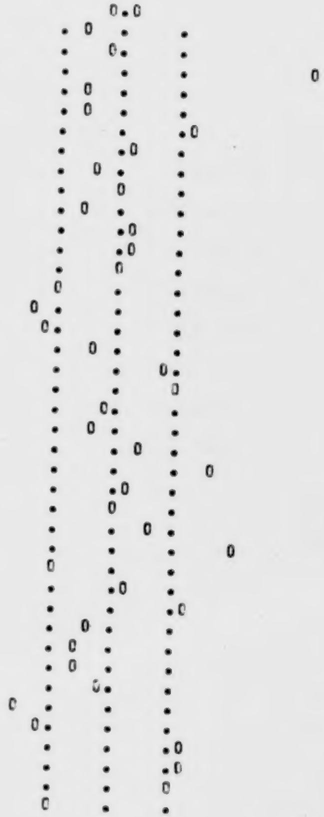

VACHSE  0.143E+05  0.128E+03 -0.982E+04 -0.643E+02  0.159E+07 -0.789E+03 -0.630E+05
IZONED -0.521E+04 -0.266E+02 -0.277E+04  0.229E+02 -0.789E+03  0.665E+05 -0.389E+04
(CONSTANT) -0.152E+04 -0.144E+02 -0.237E+04 -0.791E+01 -0.630E+05 -0.389E+04  0.516E+04
```

```
 ID     ACTUAL       FITTED                                   RESIDUAL

  1     71.00        146.8                                     -75.8
  2     15.00        42.99                                     -28.0
  3     572.0        216.0                                      356.
  4     28.00        106.1                                     -78.1
  5     73.00        153.6                                     -80.6
  6     307.0        186.0                                      121.
  7     340.0        321.9                                      18.1
  8     37.00        89.26                                     -52.3
  9     437.0        440.8                                     -3.83
 10     75.00        143.6                                     -68.6
 11     500.0        489.9                                      10.1
 12     196.0        188.6                                      7.41
 13     161.0        167.5                                     -6.47
 14     54.00        177.2                                     -123.
 15     13.00        187.4                                     -174.
 16     103.0        237.3                                     -134.
 17     106.0        163.9                                     -57.9
 18     809.0        728.2                                      80.8
 19     444.0        331.0                                      113.
 20     289.0        307.4                                     -18.4
 21     118.0        171.8                                     -53.8
 22     65.00        15.60                                      49.4
 23     230.0        62.65                                      167.
 24     152.0        133.1                                      18.9
 25     382.0        382.4                                     -.356
 26     9.000       -47.67                                      56.7
 27     503.0        278.9                                      224.
 28     62.00        178.9                                     -117.
 29     100.0        76.24                                      23.8
 30     580.0        449.8                                      130.
 31     247.0        295.6                                     -48.6
 32     41.00        103.3                                     -62.3
 33     98.00        178.6                                     -80.6
 34     193.0        215.7                                     -22.7
 35     203.0        389.1                                     -186.
 36     19.00        167.6                                     -149.
 37     215.0        88.36                                      127.
 38     123.0        3.836                                      119.
 39     129.0        18.57                                      110.
 40     213.0        324.1                                     -111.
```

PLOT OF ACTUAL(*) AND FITTED(+) VALUES

PLOT OF RESIDUALS(0)



9. <u>OTHER Equation</u>

```
EQUATION  9
***********

SMPL VECTOR
   1  40

ORDINARY LEAST SQUARES

VARIABLES...

     OTHER
     RRMILE
     PERCAP
     VACHSE
     PERCHG
     INTDEN
     RZONED
     C

MEAN OF DEPENDENT VARIABLE IS   454.2336

INDEPENDENT        ESTIMATED            STANDARD               T-              MEAN OF
 VARIABLE          COEFFICIENT           ERROR              STATISTIC          VARIABLE

RRMILE           1134.43140           180.363739           6.28568620        0.46907347

PERCAP             -0.30198252          0.06326723         -4.77312660     9726.22266

VACHSE         -12175.2109           4832.33594            -2.51952839        0.03909981

PERCHG            648.979980          341.266602           1.50167999        0.25504965

INTDEN           -295.404785          199.359222          -1.48177052        0.18093479

RZONED            403.809326          275.664795           1.46485615        0.33849955

C                3086.53931           692.318848           4.45826244        1.00000000

R-SQUARED =  0.6721

DURBIN-WATSON STATISTIC (ADJ. FOR  0 GAPS) =  2.3041

NUMBER OF OBSERVATIONS =   40

SUM OF SQUARED RESIDUALS =          .524491E+07

STANDARD ERROR OF THE REGRESSION =          398.668

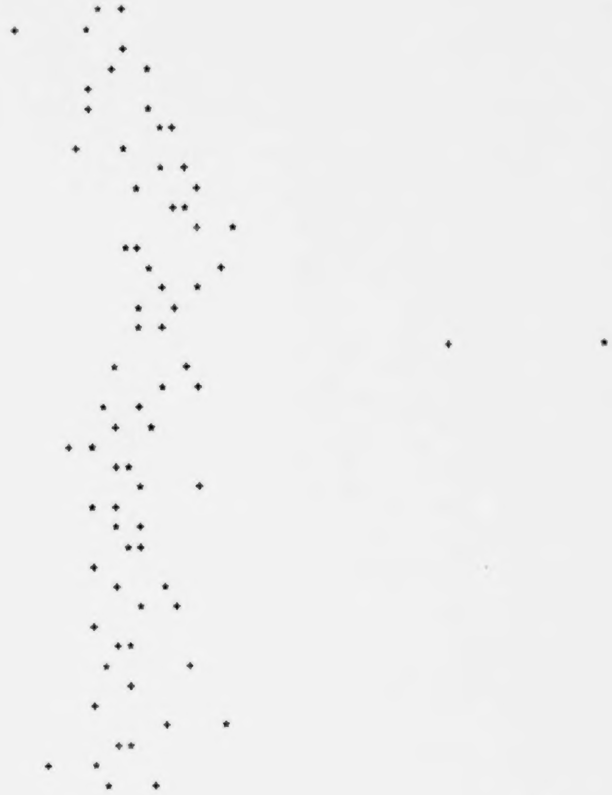
ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS
         RRMILE     PERCAP     VACHSE     PERCHG     INTDEN     RZONED    (CONSTANT)
RRMILE  0.325E+05 -0.104E+01  0.158E+06  0.123E+05  0.813E+04  0.122E+05 -0.200E+05
PERCAP -0.104E+01  0.400E-02  0.114E+03 -0.101E+02  0.414E+01 -0.368E+01 -0.398E+02
VACHSE  0.158E+06  0.114E+03  0.234E+08 -0.453E+06  0.109E+06  0.401E+06 -0.213E+07
PERCHG  0.123E+05 -0.101E+02 -0.453E+06  0.116E+06  0.543E+04  0.813E+03  0.789E+05

INTDEN  0.813E+04  0.414E+01  0.109E+06  0.543E+04  0.397E+05  0.101E+05 -0.603E+05
RZONED -0.122E+05 -0.368E+01  0.401E+06  0.813E+03  0.101E+05  0.760E+05 -0.134E+05
[illegible] -0.200E+05 -0.398E+02 -0.213E+07  0.789E+05 -0.603E+05 -0.134E+05  0.479E+06
```

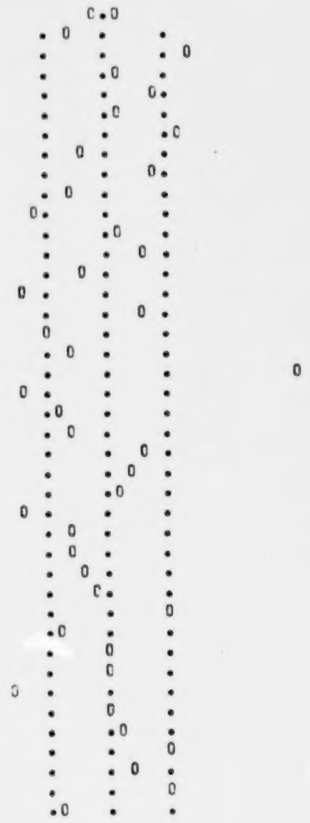
```
 ID     ACTUAL       FITTED        RESIDUAL

  1     85.70        279.8          -194.
  2     50.00       -521.3           571.
  3     353.2        298.4           54.8
  4     486.1        197.7           288.
  5     83.70        1.213           82.5
  6     548.6        40.70           508.
  7     578.2        730.6          -152.
  8     308.8       -26.88           336.
  9     603.7        811.8          -208.
 10     403.4        889.2          -486.
 11     763.6        645.2           118.
 12     1124.        853.9           270.
 13     304.4        453.3          -149.
 14     477.8        1034.          -557.
 15     866.2        627.2           239.
 16     377.0        720.1          -343.
 17     434.4        625.0          -191.
 18     4044.        2803.          .124E+04
 19     268.7        761.4          -493.
 20     558.5        889.6          -331.
 21     160.6        370.6          -210.
 22     532.6        257.4           275.
 23     82.20       -118.2           200.
 24     288.2        236.4           51.8
 25     389.8        922.3          -532.
 26     33.10        228.6          -195.
 27     230.7        451.3          -221.
 28     274.6        409.3          -135.
 29     41.10        83.55          -42.4
 30     642.2        234.0           408.
 31     414.0        712.9          -299.
 32     38.30        16.05           22.2
 33     282.9        253.9           29.0
 34     146.9        754.9          -608.
 35     316.7        274.7           42.0
 36     58.30        .8671           57.4
 37     1016.        631.5           385.
 38     309.1        182.9           126.
 39     45.40       -321.9           367.
 40     146.3        474.3          -328.
```

PLOT OF ACTUAL(*) AND FITTED(+) VALUES



PLOT OF RESIDUALS(0)



10. RY1 Equation

```
PREDICTIVE EQUATION REGRESSION                                                          02/17/78        PAGE  1[illegible]

FILE   PREDICT  (CREATION DATE = 02/17/78)

* * * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                        REGRESSION LIST  1
DEPENDENT VARIABLE..     RY1

VARIABLE(S) ENTERED ON STEP NUMBER  6..     HOSCHG

MULTIPLE R           0.90528                       ANALYSIS OF VARIANCE     DF        SUM OF SQUARES        MEAN SQUARE           F
R SQUARE             0.81953                       REGRESSION                6.             6.05352            1.00892          12.[illegible]
ADJUSTED R SQUARE    0.75584                       RESIDUAL                 17.             1.33304            0.07841
STANDARD ERROR       0.28002

------------------ VARIABLES IN THE EQUATION ------------------               ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE             B              BETA      STD ERROR B         F           VARIABLE       BETA IN       PARTIAL    TOLERANCE          F

KIDS         0.13729120D-01       0.62662       0.00246        31.204        DUACRE          0.05454       0.09318     0.54077         0.140
CAPCHG      -0.91820930D-03      -0.71293       0.00017        29.465        VACHSF         -0.26276      -0.43045     0.48430         3.635
SERVED       0.7842406            0.36504       0.24118        10.577        INCOME         -0.01223      -0.02612     0.95403         0.013
OZONED        22.70408            0.37074       7.17613        10.010        VACOFF         -0.09034      -0.16171     0.73006         0.546
STAY         -2.980871           -0.44621       0.91678        10.572        UNEMP          -0.11446      -0.19912     0.54615         0.661
HOSCHG      -0.1814667           -0.27103       0.08151         4.957        OFFJOB          0.11675       0.21063     0.55404         0.738
(CONSTANT)    4.531282                                                       WWJOB          -0.05793      -0.12612     0.85528         0.259
                                                                             MANJOB          0.09420       0.16660     0.56449         0.457
                                                                             JOBS            0.07624       0.13644     0.57791         0.303
                                                                             NONHH           0.15144       0.26022     0.53281         1.162
                                                                             POOR           -0.02842      -0.04142     0.38337         0.027
                                                                             VALUE          -0.03401      -0.07466     0.86576         0.090
                                                                             ROOMS           0.03260       0.06445     0.70200         0.067
                                                                             UNIV           -0.02777      -0.04533     0.40079         0.033
                                                                             RELJOB          0.14174       0.26080     0.61096         1.166
                                                                             RELWW           0.02778       0.04865     0.55355         0.038
                                                                             RELOFF          0.15486       0.28305     0.60289         1.393
                                                                             RELMAN          0.13849       0.25251     0.59996         1.090
                                                                             GOVT            0.13578       0.29404     0.84634         1.514
                                                                             LAND            0.00538       0.01061     0.70064         0.002
                                                                             POPDEN          0.06993       0.12410     0.56828         0.250
                                                                             DISCBD          0.13294       0.24467     0.61132         1.019
                                                                             RRMILE         -0.02344      -0.04468     0.66142         0.032
                                                                             ACCESS         -0.05721      -0.10978     0.66447         0.195
                                                                             INTDEN         -0.22505      -0.43386     0.67071         3.710
                                                                             TRANS          -0.14391      -0.30008     0.78467         1.583
                                                                             AIRPRT          0.12987       0.25754     0.70572         1.137
                                                                             VACANT          0.09974       0.22201     0.89415         0.829
                                                                             RZONED          0.00995       0.02067     0.77921         0.007
                                                                             CZONED         -0.00005      -0.00010     0.78694         0.000
                                                                             IZONED         -0.19561      -0.35752     0.60161         2.345
                                                                             LIMITS         -0.09560      -0.20442     0.82521         0.696
                                                                             POLICY          0.00641       0.01553     0.97200         0.006
                                                                             TLIMIT         -0.13160      -0.26743     0.85830         1.441
                                                                             TPOLIC          0.02215       0.05103     0.95776         0.042
```

11. <u>RY2 Equation</u>

```
PREDICTIVE EQUATION REGRESSION                                                         02/17/78        PAGE  [illegible]

FILE    PREDICT  (CREATION DATE = 02/17/78)

* * * * * * * * * * * * * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                   REGRESSION LIST  1
DEPENDENT VARIABLE..    RY2

VARIABLE(S) ENTERED ON STEP NUMBER  5..    PEAK

MULTIPLE R            0.91390                  ANALYSIS OF VARIANCE      DF       SUM OF SQUARES          MEAN SQUARE             F
R SQUARE              0.83521                  REGRESSION                 5.           10.21168              2.04234          16.245[illegible]4
ADJUSTED R SQUARE     0.78943                  RESIDUAL                  18.            2.01482              0.11193
STANDARD ERROR        0.33457

----------------- VARIABLES IN THE EQUATION ------------------            ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE            B             BETA      STD ERROR B         F        VARIABLE      BETA IN      PARTIAL    TOLERANCE           F

HSECHG      4.376418           0.70395        0.68429       40.903       DUACRE       -0.12596     -0.28378     0.83642         1.489
PCOR       -5.479691          -0.48705        1.25251       19.140       VACHSE       -0.03643     -0.06859     0.58395         0.080
OZONED     -34.05850          -0.43228        8.21178       17.202       INCOME       -0.16502     -0.36047     0.78633         2.535
RRMILE      0.7322320          0.35431        0.20536       12.714       VACOFF       -0.01948     -0.04175     0.75687         0.030
PEAK        0.3645832D-01      0.26902        0.01399        6.795       UNEMP         0.09182      0.19016     0.70678         0.638
(CONSTANT)  0.2180154                                                    OFFJOB       -0.09540     -0.21990     0.87553         0.864
                                                                         WWJOB        -0.11675     -0.23911     0.69123         1.031
                                                                         MANJOB       -0.11818     -0.24756     0.72305         1.110
                                                                         JOBS         -0.13060     -0.28737     0.75792         1.530
                                                                         NONHH         0.08944      0.17039     0.59812         0.508
                                                                         VALUE        -0.00964     -0.01778     0.56073         0.005
                                                                         ROOMS        -0.11141     -0.19952     0.52848         0.705
                                                                         KIDS          0.20724      0.40725     0.63635         3.380
                                                                         UNIV         -0.07755     -0.17199     0.81047         0.518
                                                                         RELJOB       -0.06540     -0.15745     0.95514         0.432
                                                                         RELWW        -0.04696     -0.11392     0.96956         0.224
                                                                         RELOFF       -0.06020     -0.14405     0.94348         0.360
                                                                         RELMAN       -0.06482     -0.15703     0.96716         0.430
                                                                         GOVT          0.10107      0.23667     0.90357         1.009
                                                                         LAND         -0.03663     -0.07876     0.76183         0.106
                                                                         POPDEN       -0.11975     -0.26764     0.62320         1.312
                                                                         DISCBD        0.04387      0.09361     0.75030         0.150
                                                                         ACCESS        0.15481      0.30910     0.65692         1.796
                                                                         INTDEN       -0.01197     -0.02651     0.80816         0.012
                                                                         TRANS        -0.03470     -0.07860     0.84525         0.106
                                                                         AIRFRT        0.05836      0.13107     0.83137         0.297
                                                                         VACANT        0.07971      0.16469     0.70522         0.475
                                                                         RZONED       -0.13711     -0.27341     0.65524         1.373
                                                                         CZONED       -0.07273     -0.16673     0.86595         0.486
                                                                         IZONED        0.06877      0.12478     0.54246         0.269
                                                                         LIMITS        0.06309      0.13922     0.80256         0.336
                                                                         POLICY       -0.13690     -0.30266     0.80549         1.714
                                                                         TLIMIT        0.00657      0.01980     0.86011         0.007
                                                                         TPOLIC       -0.14013     -0.31105     0.81195         1.821
                                                                         DRIVE        -0.11299     -0.23721     0.72629         1.014
```

12. <u>CY1 Equation</u>

```
                                                                              02/14/78         PAGE   45
PREDICTIVE EQUATION REGRESSION

FILE   PREDICT  (CREATION DATE = 02/14/78)                                                              VARIABLE LIST  1
* * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *   REGRESSION LIST  1

DEPENDENT VARIABLE..     CY1

VARIABLE(S) ENTERED ON STEP NUMBER  5..    TLIMIT
                                                                                                                  F
                                            ANALYSIS OF VARIANCE        DF       SUM OF SQUARES       MEAN SQUARE
MULTIPLE R              0.85281             REGRESSION                   5.            30.33250           6.06650        18.13451
R SQUARE                0.72729             RESIDUAL                    34.            11.37395           0.33453
ADJUSTED R SQUARE       0.68718
STANDARD ERROR          0.57838
                                                                    -------------- VARIABLES NOT IN THE EQUATION ---------------

----------------- VARIABLES IN THE EQUATION ------------------      VARIABLE        BETA IN      PARTIAL    TOLERANCE          F

VARIABLE            B           BETA      STD ERROR B        F      DUACRE         -0.14644     -0.24635     0.78442          2.165
                                                                    VACHSE         -0.02242     -0.04106     0.91450          0.056
VACOFF     -0.2154105        -0.61369       0.03275       43.249    INCOME         -0.00684     -0.01259     0.92352          0.005
LIMITS      0.5069719         0.67519       0.07750       42.790    UNEMP          -0.01060     -0.01763     0.77236          0.010
CAPAC2     -0.2320196D-01    -0.41751       0.00524       19.616    OFFJOB         -0.13488     -0.23770     0.84695          1.976
KIDS        0.1589771D-01     0.37027       0.00415       14.693    WWJOB           0.01035      0.01973     0.99218          0.013
TLIMIT     -0.6026462D-01    -0.30139       0.02182        7.630    MANJOB         -0.16641     -0.29380     0.85009          3.118
(CONSTANT)  -2.265219                                               JOBS           -0.14705     -0.25320     0.86654          2.261
                                                                    NONWH           0.09387      0.16934     0.88754          0.974
                                                                    POOR            0.13968      0.22271     0.69328          1.722
                                                                    VALUE          -0.09852     -0.16907     0.80323          0.971
                                                                    ROOMS          -0.00588     -0.00946     0.70715          0.003
                                                                    UNIV           -0.09690     -0.13644     0.55662          0.645
                                                                    RELJOB         -0.06587     -0.12387     0.96438          0.514
                                                                    RELWW          -0.09269     -0.17273     0.94706          1.015
                                                                    RELOFF         -0.06899     -0.13023     0.97178          0.569
                                                                    RELMAN         -0.08381     -0.15852     0.97557          0.851
                                                                    GOVT            0.09440      0.15883     0.77205          0.854
                                                                    LAND           -0.06013     -0.10776     0.87550          0.388
                                                                    POPDEN         -0.13875     -0.24614     0.85825          2.128
                                                                    DISCBD         -0.19571     -0.34546     0.84986          4.473
                                                                    RRMILE          0.02061      0.03726     0.89158          0.046
                                                                    ACCESS         -0.11742     -0.19754     0.77180          1.340
                                                                    INTDEN         -0.06502     -0.10996     0.77986          0.404
                                                                    TRANS          -0.01726     -0.02995     0.82081          0.030
                                                                    AIRPRT         -0.05060     -0.08382     0.74582          0.233
                                                                    VACANT          0.05475      0.09269     0.78493          0.287
                                                                    RZONED         -0.05557     -0.08860     0.69325          0.261
                                                                    CZONED         -0.11706     -0.21190     0.89364          1.551
                                                                    OZONED          0.14543      0.25243     0.82170          2.246
                                                                    IZONED          0.05372      0.08950     0.75084          0.266
                                                                    POLICY          0.05027      0.08437     0.76813          0.237
                                                                    TPOLIC          0.06600      0.10256     0.62065          0.351
                                                                    DRIVE          -0.10497     -0.16625     0.68415          0.938
                                                                    RIDET          -0.00138     -0.00197     0.55942          0.000
```

13. <u>CY2 Equation</u>

```
PREDICTIVE EQUATION REGRESSION                                                        02/14/78         PAGE  41

FILE    PREDICT   (CREATION DATE = 02/14/78)

* * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                  REGRESSION LIST  1

DEPENDENT VARIABLE..    CY2

VARIABLE(S) ENTERED ON STEP NUMBER  5..    VACANT

                                                   ANALYSIS OF VARIANCE     DF      SUM OF SQUARES         MEAN SQUARE             F
MULTIPLE R            0.80663                      REGRESSION                5.          41.14118             8.22824          12.66483
R SQUARE              0.65065                      RESIDUAL                 34.          22.08952             0.64969
ADJUSTED R SQUARE     0.59928
STANDARD ERROR        0.80603

------------------ VARIABLES IN THE EQUATION ------------------            ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE            B              BETA      STD ERROR B         F          VARIABLE      BETA IN      PARTIAL   TOLERANCE         F

PHASE        -1.538799          -0.61119       0.26545       33.603         DUACRE        0.04180      0.05726     0.65594       0.109
TRANS        -0.4589325D-02     -0.48208       0.00106       18.920         VACHSE       -0.06327     -0.09540     0.79421       0.303
DISCBD       -0.1779279D-01     -0.42150       0.00461       14.872         INCOME       -0.07297     -0.11904     0.92956       0.474
GOVT         -0.4169631D-02     -0.29076       0.00152        7.491         VACOFF       -0.10941     -0.17081     0.85151       0.992
VACANT        1.484964           0.25541       0.62051        5.727         UNEMP        -0.17053     -0.26649     0.85310       2.523
(CONSTANT)   -0.5360620                                                     OFFJOB        0.14171      0.19066     0.63238       1.245
                                                                            WWJOB         0.06140      0.09586     0.85149       0.306
                                                                            MANJOB       -0.12059     -0.19289     0.89386       1.275
                                                                            JOBS          0.04876      0.07013     0.72261       0.163
                                                                            NONHH         0.13476      0.21902     0.92272       1.663
                                                                            POOR          0.07982      0.11169     0.68399       0.417
                                                                            VALUE         0.02092      0.03291     0.86453       0.036
                                                                            ROOMS        -0.00608     -0.00907     0.77612       0.003
                                                                            KIDS         -0.09082     -0.12926     0.70770       0.561
                                                                            UNIV          0.10672      0.12613     0.48792       0.533
                                                                            RELJOB       -0.10005     -0.12888     0.57968       0.557
                                                                            RELWW         0.03920      0.04531     0.46686       0.068
                                                                            RELOFF       -0.14456     -0.19766     0.65319       1.342
                                                                            RELMAN       -0.21026     -0.30112     0.71651       3.291
                                                                            LAND          0.03009      0.04512     0.78574       0.067
                                                                            POPDEN        0.02348      0.03301     0.69068       0.036
                                                                            RRMILE        0.11415      0.18692     0.93668       1.195
                                                                            ACCESS       -0.04111     -0.06520     0.87877       0.141
                                                                            INTDEN       -0.05989     -0.08790     0.75259       0.257
                                                                            AIRPRT        0.06320      0.09367     0.76744       0.292
                                                                            RZONED       -0.02819     -0.04310     0.81662       0.061
                                                                            CZONED        0.07065      0.11010     0.84837       0.405
                                                                            OZONED       -0.13881     -0.21978     0.87576       1.675
                                                                            IZONED       -0.05335     -0.07414     0.67450       0.182
                                                                            LIMITS        0.20292      0.31177     0.82471       3.553
                                                                            POLICY        0.01421      0.02277     0.89691       0.017
                                                                            TLIMIT        0.00874      0.01377     0.86814       0.006
                                                                            TPOLIC        0.01234      0.01982     0.50116       0.013
                                                                            DRIVE        -0.11490     -0.15150     0.60742       0.775
                                                                            RIDET        -0.04789     -0.06650     0.71477       0.156
```

APPENDIX B

GLOSSARY OF TERMS

A dependent variable is the output variable of a mathematical function, which has as its arguments one or more input or independent variables.

Given a set of interrelated variables, an exogenous variable is one whose value is determined by forces external to or outside the system of relationships. An endogenous variable is an internal variable of the system which is completely determined (i.e., caused) by one or more exogenous and/or endogenous variables. The relationships of any one endogenous variable can be translated into mathematical form by designating it as the dependent variable of a function whose independent variables are all related causal factors, whether they be endogenous or exogenous variables.

Instrumental variables are exogenous variables which are introduced into nonrecursive systems of causal relationships (i.e., those involving interactions between endogenous variables) to allow the estimation of structural coefficients. A detailed list of conditions associated with instrumental variables is given in Heise [17].

A wastewater major project is defined as the construction or extension of interceptor or collector sewer lines during the period 1958 to 1963 in a community in the United States. If construction date information is not available, then a grant funding date in the period 1956-1960 is acceptable. The project had to affect an increase in absolute system collection capacity of 1 MGD or more, and had to cost a minimum of $200,000 to construct. Phased projects are considered if the first phase of construction on the collection network was complete within 1958-1963 and the last phase of construction was complete by 1965.

Induced development is defined as urban land use associated with, caused, stimulated, or allowed by, or located because of the construction and operation of a major project.

Secondary development is induced development which has a direct causal relationship with a major project.

Tertiary development is induced development which has a direct causal relationship with secondary development, and so is only indirectly related to a major project.

The drainage basin of a wastewater project is defined as the land area which drains, by gravity, to any point of the collection network of the major project. In the case of essentially flat terrain (e.g., river deltas), this area is restricted to the locus of points no greater than 1,000 feet from any point along the interceptor line of the major project.

The legal service area of a wastewater major project is defined as the drainage basin of the major project plus any additional areas connected to the collection network by pumping stations and force mains.

The area of analysis is defined as the legal service area of a wastewater major project in the base year. It must be a minimum size of 5,000 acres (or approximately 8 square miles), and contain significant amounts of vacant developable land, some of which must be more than 5,000 feet from the nearest interceptor line in the base year.

"201" refers to Section 201 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). Section 201 calls for detailed planning for the wastewater treatment facilities needed to achieve the goals of the Act.

"208" refers to Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). Section 208 provides for the designation of state and areawide agencies for the purpose of developing effective water quality management plans for areas that, because of "urban-industrial concentrations" or other factors, have "substantial water quality control problems." The approach is aimed at integrating controls over municipal and industrial wastewater, storm sewer runoff, nonpoint source pollutants and land use.

APPENDIX C

DEFINITION OF MODEL VARIABLES

This appendix summarizes the model variables used in the GEMLUP-II model. A complete discussion of variable selection is given in Section II.G of the first volume report [12]. Table C-1 lists the definitions of endogenous model variables, while Table C-2 summarizes the definitions of exogenous model variables, both in English units. The metric units of those variables actually used in the predictive model and worksheets are listed in Table C-3.

TABLE C-1

DEFINITION OF ENDOGENOUS MODEL VARIABLES

Name	Description	Land Use Codes [106]	
RES	Number of dwelling units per 10,000 acres of area of analysis in 1970.	11	Household units
		12	Group quarters
		13	Residential hotels
		14	Mobile home parks or courts
		19	Other residential
COMM	Commercial land use per 10,000 acres of area of analysis in 1970 in 1,000 square feet.	52-59	Retail trade
		62	Personal services
		64	Repair services
		66	Contract construction services
OFFICE	Office-Professional services land use per 10,000 acres of area of analysis in 1970 in 1,000 square feet.	61	Finance, insurance, and real estate services
		631-636 638,639	Business services (excludes warehousing)
		65	Professional services
		692	Welfare and Charitable services
		699	Other services
MANF	Manufacturing land use per 10,000 acres of area of analysis in 1970 in 1,000 sq. ft.	2,3	Manufacturing
WHOLE	Wholesale-warehousing land use per 10,000 acres of area of analysis in 1970 in 10,000 square feet.	51	Wholesale trade
		637	Warehousing and storage services
HIWAYS	Non-expressway highway lane miles per 10,000 acres of area of analysis in 1970.	45	Highway and street right-of-way
EDUC	Educational land use per 10,000 acres of area of analysis in 1970 in 1,000 square feet.	681	Nursery, primary, and secondary education

TABLE C-1 (CONTINUED)

DEFINITION OF ENDOGENOUS MODEL VARIABLES

Name	Description	Land Use Codes [106]	
REC	Active, outdoor recreational land use per 10,000 acres of area of analysis in 1970 in acres.	73	Amusements
		74	Recreational activities
		75	Resorts and group camps
OTHER	Other urban land uses per 10,000 acres of area of analysis in 1970 in 1,000 square feet.	15	Transient lodgings
		691	Religions activities
		71	Cultural activities and nature exhibitions
		79	Other cultural, entertainment, and recreational

TABLE C-2

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
Service Area Base Year Characteristics: Socioeconomic Variables	
DUACRE = Dwelling units per mile^2 in area of analysis in 1960.	
= (100*du60)/acre	
where: du60 = 1960 census tracts* housing units in 100s	Census
acre = 1960 area of census tracts in miles^2	Census
VACHSE = Percent vacant available dwelling units in area of analysis in 1960.	Census
INCOME = Relative medium income of families and unrelated individuals in area of analysis compared to county income levels in 1960.	
= (10*inc)/median	
where: inc = 1960 median income for families in census tracts in $10s	Census
median = 1960 median income for families in the county**	Census
VACOFF = Vacancy rate of office buildings in area of analysis in 1960.	BOMA/Planning Agency
UNEMP = Unemployment rate in area of analysis (census tracts) in 1960.	Census
OFFJOB = Office employment per mile^2 in area of analysis in 1960.	
= (100*smoff)/acre	
where: smoff = 1960 office employment in census tracts in 100s***.	Census
WWJOB = Warehouse and wholesale employment per mile^2 in area of analysis in 1960.	
= (100*wwemp)/acre	
where: wwemp = 1960 employment in wholesale trade+ in census tracts in 100s.	Census

---

* Census tracts refers to those tracts most closely approximating the area of analysis in areal extent.

** County refers to the county containing most of the legal service area.

*** Fire, Business Services, Public Administration, and Repair Services.

+ Trucking, Warehousing, and Wholesale Trade.

TABLE C-2 (CONTINUED)

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
MANJOB = Manufacturing employment per mile^2 in area of analysis in 1960. = (100*manemp)/acre where: manemp = 1960 manufacturing employment in census tracts in 100s.	Census
JOBS = Total employment per mile^2 in area of analysis in 1960. (100*totemp)/acre where: totemp = 1960 total civilian employment in census tracts in 100s.	Census
NONHH = Non-household population per mile^2 in area of analysis in 1960. = (100*nonh60)/acre where: nonh60 = 1960 population in group quarters in census tracts in 100s.	Census
POOR = Percent of total families with income below $3,000 in area of analysis (census tracts) in 1960.	Census
RENTS* = Percent of total housing units that are renter occupied in area of analysis in 1960.	Census
VALUE = Median value of housing units in area of analysis (census tracts) in 1960.	Census
ROOMS = Median number of rooms in housing units in area of analysis (census tracts) in 1960.	Census
KIDS = School age children per 100 households in area of analysis in 1960. = 100*sch60/du60 where: sch60 = 1960 population 0-14 years of age in census tracts in 100s.	Census

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* Used only in the disaggregation analysis of RES.

TABLE C-2 (CONTINUED)

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
UNIV = Categorical variable to indicate the presence or absence of a college or university in the area of analysis in 1960. where: 1 = a college or university existed in census tracts in 1960. 0 = none existed.	Planning Agency
RELJOB = Relative employment density of the area of analysis in 1960. = JOBS/(100*rempl/areal) where: rempl = 1960 total employment in the SMSA in 100s.	Census
areal = 1960 SMSA land area in mile^2.	Census
RELWW = Relative warehouse and wholesale employment density of the area of analysis in 1960. = WWJOB/(100*rwwemp/areal) where: rwwemp = 1960 employment in warehouse and wholesale trade in the SMSA in 100s.	Census
RELOFF = Relative office employment density in the area of analysis in 1960. = OFFJOB/(100*roffl/areal) where: roffl = 1960 SMSA office employment in 100s.	Census
RELMAN = Relative manufacturing employment density of the area of analysis in 1960. = MANJOB/(100*rempl*manper/areal) where: manper = percent of 1960 total SMSA employment in manufacturing.	Census
GOVT = Total county government expenditures in 1962 in 10^6 \$.	Census
LAND = Price of vacant land in area of analysis in 1960 relative to median regional income. = price/median where: price = median price of one acre of residential vacant land (\$) in area of analysis in 1960.	Planning Agency

TABLE C-2 (CONTINUED)

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
POPDEN = Population density of the area of analysis in 1960 in persons per mile^2.	
= (100*pop)/acre	
where: pop = total population of census tracts in 1960 in 100s.	Census
SFDET = Percent of housing that is single family detached in area of analysis in 1970.	
= unit1/hse70	
where: unit1 = number of single family detached units in census tracts in 1970 in 100s.	Census
hse70 = total number of housing units in census tracts in 1970 in 100s.	Census
MF = Percent of housing that is multifamily in area of analysis in 1970.	
= (unit34+unit5+unit50)/hse70	
where: unit34 = number of 3 and 4 family housing units in census tracts in 1970 in 100s.	Census
unit5 = number of 5-49 family housing units in census tracts in 1970 in 100s.	Census
unit50 = number of 50$^+$ family housing units in census tracts in 1970 in 100s.	
SFATT = ((hse70-unit1)/hse70)-MF	
= Percent of housing that is single family attached in area of analysis in 1970.	
PCOMM1 = Percent of commercial development less than 50,000 ft^2 in floor area.	
= comm1/(comm1 + comm2 + comm3)	
where: comm1 = total commercial floor space in 1,000 ft^2 in area of analysis in 1970 for buildings with less than 50,000 ft^2.	Planning Agency
comm2 = total commercial floor space in 1,000 ft^2 in 1970 in area of analysis for buildings with less than 100,000 ft^2 but greater than 50,000 ft^2.	
comm3 = total commercial floor space in 1,000 ft^2 in 1970 in area of analysis for buildings with greater than 100,000 ft^2.	

TABLE C-2 (CONTINUED)
DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
PCOMM2 = Percent of commercial development with floor area between 50,000 and 100,000 ft^2. = comm2/(comm1 + comm2 + comm3)	
PCOMM3 = Percent of commercial development with floor area greater than 100,000 ft^2. = comm3/(comm1 + comm2 + comm3)	
Service Area Base Year Characteristics: Accessibility	
DISCBD = Distance in miles from centroid of area of analysis to centroid of nearest CBD* in year (t + 0)**	USGS topographic map
RRMILE = Railroad mileage per mile^2 in the area of analysis analysis in year (t + 0) = (rail*640)/AREA where: rail = railroad mileage in area of analysis in year (t + 0)	USGS topographic map
ACCESS = Limited-access highway interchanges per mile^2 in area of analysis in year (t + 5) = (intchg*640)/AREA where: intchg = number of limited access interchanges in area of analysis in year (t + 5)	USGS topographic map/ Planning Agency
INTDEN = Relative limited-access highway interchange density of the area of analysis in year (t + 5) = ACCESS/(ctyacc*640/county) where: ctyacc = number of limited access interchanges in the county in year (t + 5) county = area of county in mile^2	USGS topographic map/ Planning Agency
TRANS = Number of transit stops (bus and commuter rail) in the area of analysis in year (t + 0)	Planning Agency
AIRPRT = Distance in miles from centroid of area of analysis to centroid of nearest commercial airport in the year (t + 0)	USGS topographic map

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* Central Business District, defined as the center of the nearest urban area with population exceeding 100,000.

**t is the year the wastewater major project was completed and became operational.

TABLE C-2 (CONTINUED)

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
Service Area Base Year Characteristics: Land Use Constraints	
AREA = Area of analysis in acres	Project Data
VACANT = Percent vacant developable acreage in area of analysis in year (t + 0) = vacdev/(AREA-vacund)	
where: vacdev = vacant developable acreage in area of analysis in year (t + 0)	Planning Agency
vacund = vacant undevelopable acreage in area of analysis in year (t + 0)	Planning Agency
RZONED = Percent of total acreage zoned for residential use in the area of analysis in year (t + 0) = rzone/AREA	
where: rzone = acres of land zoned for residential use in the area of analysis in year (t + 0)	Planning Agency
CZONED = Percent of total acreage zoned for commercial use in the area of analysis in year (t + 0) = czone/AREA	
where: czone = acres of land zoned for commercial use in the area of analysis in year (t + 0)	Planning Agency
OZONED = Percent of total acreage zoned for office use in the area of analysis in year (t + 0) = ozone/AREA	
where: ozone = acres of land zoned for office use in the area of analysis in year (t + 0)	Planning Agency
IZONED = Percent of total acreage zoned for industrial use in the area of analysis in year (t + 0) = izone/AREA	
where: izone = acres of land zoned for industrial use in the area of analysis in year (t + 0)	Planning Agency
SOILS = Percentage of total area of analysis having a "severe" soil type classification for urban development suitability = soil/AREA where: soil = Acreage in area of analysis with a "severe" soil type classification with regard to suitability for urban development.	Planning Agency/Soil Conservation Service (SCS)

TABLE C-2 (CONTINUED)

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
ONLOT = Percentage of total area of analysis having a "severe" soil type classification for on-lot sewage disposal suitability. = onsite/AREA where: onsite = Acreage in area of analysis with a "severe" soil type classification for on-lot sewage disposal suitability.	Planning Agency/SCS
LIMITS = Categorical variable to indicate the severity of governmental restrictions on on-lot sewage disposal during the period (t + 0) to 1970. where: 4 = on-lot disposal is prohibited entirely. 3 = on-lot disposal is prohibited except on large lots. 2 = on-lot disposal is permitted but percolation tests are required. 1 = on-lot disposal is permitted but package plants are prohibited. 0 = no restrictions.	Planning Agency/ Local Government
POLICY = Categorical variable to indicate the presence or absence of governmental policies designed to limit the number of hookups to the sewerage system in area of analysis anytime during the period (t + 0) to 1970. Examples are sewer moratoria and rationed connections. where: 1 = policies on hookup limitations existed 0 = policies did not exist.	Planning Agency/ Local Government
TLIMIT = The number of years during the period of analysis that on-site sewage disposal was limited = 1970-ylimit where: ylimit = the year on-site disposal limitations went into effect (or 1970 if no restrictions).	Planning Agency/ Local Government
TPOLIC = The number of years during the period of analysis that sewer system hookup limitations were in effect = 1970-ypolic where: ypolic = the year limitations on sewage system hookups went into effect (or 1970 if no restrictions)	Planning Agency/ Local Government

TABLE C-2 (CONTINUED)

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
Regional Growth Factors	
ENERGY = Relative electrical energy cost factor in municipality compared to average U.S. commercial rate in 1960. = encost/$51.59 where: encost = cost of energy for commercial users in 1960 in units of dollars per 1500 KWh.	Census
DRIVE = 100s of workers who drive per mile^2 in the county in 1960. = (autoco)/county where: autoco = workers who drive to work in county in 1960 in 100s.	Census
RIDET = Workers who ride mass transit per mile^2 in the county in 1960. = massco/county where: massco = workers who use mass transit in county in 1960 in 100s.	Census
PERCHG = Percent change in county population 1960-1970	Census
DENCHG = Population density change in the county 1960-1970. = (copop2/county - copop1/county) where: copop2 = county population in 1970.	Census
copop1 = county population in 1970.	Census
JOBCHG = Change in total regional employment per mile^2 1960-1970. = 100*(remp2 - remp1)/SMArea where: remp1 = 1960 total employment in SMSA in 100s.	Census
remp2 = 1970 total employment in SMSA in 100s.	Census
SMArea= area of SMSA in miles^2.	Census
HSECHG = Percent change in total regional housing units 1960-1970. = (rhse2 - rhse1)/rhse1 where: rhse1 = total housing units in SMSA in 1960 in 100s.	Census
rhse2 = total housing units in SMSA in 1970 in 100s.	Census

TABLE C-2 (CONTINUED)

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
COMCHG = Percent change in total regional retail trade* employment 1960-1970.	
= (rcom2 - rcom1)/rcom1	
where: rcom1 = total retail trade employment in SMSA in 1960 in 100s.	Census
rcom2 = total retail trade employment in SMSA in 1970 in 100s.	Census
POPDIF = Percent change in regional population 1960-1970.	Census
MANCHG = Percent change in regional manufacturing employment 1960-1970.	
= (perman*remp2-manper*remp1)/(manper*remp1)	
where: perman = % of 1970 total SMSA employment in manufacturing	Census
manper = % of 1960 total SMSA employment in manufacturing	Census
SERCHG = Percent change in regional services** employment 1960-1970.	
= (rser2 - rser1)/rser1	
where: rser1 = 1960 SMSA service employment in 100s.	Census
rser2 = 1970 SMSA service employment in 100s.	Census
HOSCHG = Percent change in regional hospital employment 1960-1970.	
= (rhosp2 - rhosp1)/rhosp1	
where: rhosp1 = 1960 SMSA hospital employment in 100s.	Census
rhosp2 = 1970 SMSA hospital employment in 100s.	Census
EDUCHG = Percent change in regional educational employment 1960-1970.	
= (red2 - red1)/red1	
where: red1 = 1960 SMSA educational employment in 100s.	Census
red2 = 1970 SMSA educational employment in 100s.	Census
OFFCHG = Percent change in regional office*** employment 1960-1970.	
= (roff2 - roff1)/roff1	
where: roff1 = 1960 SMSA office employment in 100s.	Census
roff2 = 1970 SMSA office employment in 100s.	Census

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* Food and Dairy, Eating and Drinking, and Other Retail.

** Professional and Related Services, Other Personal Services, Entertainment and Welfare and Fraternal Organizations.

*** FIRE, (Finance, Insurance, and Real Estate) Business Services, Public Administration, Repair Services, and Public Administration.

TABLE C-2 (CONTINUED)

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
PERCAP = Median family income in SMSA in 1970.	Census
EMPOP = Regional (SMSA) employment to population ratio in 1970.	Census
= remp2/rpop2	
where: rpop2 = 1970 SMSA population in 100s.	Census
CAPCHG = Change in median family SMSA income 1960-1970.	
= PERCAP - per60	
where: per60 = median family income in SMSA in 1960.	Census
STAY = Index of mobility - % of 1960 families who were in the same house in 1955.	Census
Wastewater Treatment Major Project Characteristics	
TIME = Number of years available for secondary growth to occur.	
= phyear-year	
where: phyear = the year aerial photographs were taken from which land use data was extracted.	Planning Agency
year = the year construction was completed on the major project on initial phase.	Project Data
PHASE = Categorical variable to indicate the presence or absence of phasing of the major project.	Project Data
where: 1 = phasing has occurred.	
0 = phasing has not occurred.	
COST = .Normalized per capita local costs ($) of the major project in area of analysis in year (t + 0).	
= 1,000* (totcst/pi1 - fedcst/pi2)/popcom	
where: totcst = total major project construction cost (1,000 $)	Project Data
fedcst = federally funded share of major project cost (1,000 $)	Project Data
pi1 = consumer price index for "year"	
pi2 = consumer price index for the year of federally funding of the major project	
popcom = population served by major project facility in year (t + 0)	Project Data
LENGTH = Running length of interceptor sewer lines in miles going through relatively undeveloped land (<.1 du per acre) in area of analysis in year (t + 0).	Project Data

TABLE C-2 (CONTINUED)

DEFINITION OF EXOGENOUS MODEL VARIABLES

Name - Description	Data Source
CROSS = Index of available undeveloped land in the area of analysis through which interceptor sewers go through in t + 0. = 640*LENGTH/AREA	
SERVED = Percent of the area of analysis easily served by the major project in year (t + 0) = area5k/AREA where: area5k = acres of land within 5,000 feet of the major project interceptor sewer in area of analysis in year (t + 0)	Project Data
CAPAC1 = Total hydraulic design capacity of the major project wastewater collection system in million gallons per day (mgd) in year (t + 0) (or in 1965 if a phased project)	Project Data
CAPAC2 = Total hydraulic design capacity of the major project wastewater treatment plant in mgd in year (t + 0)	Project Data
PEAK = Actual Peak flow in the major project wastewater system in mgd in year (t + 0)	Project Data
RECAP = Reserve capacity of the wastewater major project collection system in year (t + 0) = CAPAC1 - PEAK	
RECAP1 = Percent reserve capacity of the wastewater major project collection system in year (t + 0) = 100*RECAP/PEAK	
RECAP2 = Percent reserve capacity of the wastewater major project treatment plant in year (t + 0) = 100*(CAPAC2 - PEAK)/PEAK	

TABLE C-3

METRIC UNITS OF VARIABLES USED IN THE PREDICTIVE EQUATIONS AND WORKSHEETS

Variable Names		
Predictive Equations	Worksheets	Metric Units
Dependent		
RES+	Residential	Dwelling units per 10,000 square meters of area of analysis
COMM+	Commercial	Square meters of floor area per 10,000 square meters of area of analysis
OFFICE+	Office-Professional	Square meters of floor area per 10,000 square meters of area of analysis
MANF+	Manufacturing	Square meters of floor area per 10,000 square meters of area of analysis
WHOLE+	Wholesale	Square meters of floor area per 10,000 square meters of area of analysis
HIWAYS+	Highways	Lane kilometers per 10,000 square meters of area of analysis
EDUC+	Education	Square meters of floor area per 10,000 square meters of area of analysis
REC+	Recreation	Square meters of recreational land use per 10,000 square meters of area of analysis
OTHER+	Other	Square meters of floor area per 10,000 square meters of area of analysis
SFDET	% Single Family	*
SFATT	% Two Family	*
MF	% Multifamily	*
PCOMM1	% Small Comm'l	*
PCOMM2	% Med Comm'l	*
PCOMM3	% Large Comm'l	*
Independent		
VACANT	Vacant Land	*
LAND	Land Cost	*
RECAP1	% Collection Reserve	*
MANJOB	Manufacturing Density	Employees per square kilometer of area of analysis
STAY	Nonmobility	*
DRIVE	Driver Density	100s of drivers per square kilometer of area of analysis
SERVED	Sewer Service	*
KIDS	Kid Density	*
ACCESS	Interchanges	Interchanges per square kilometer of area of analysis

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* Same as English units.

+ Units for Predictive Equation variables are per 10,000 acres (square meters) of area of analysis, while units for Worksheet variables are totals for the entire area of analysis.

TABLE C-3 (CONTINUED)

METRIC UNITS OF VARIABLES USED IN THE PREDICTIVE EQUATIONS AND WORKSHEETS

Variable Names		
Predictive Equations	Worksheets	Metric Units
JOBCHG	Employment Growth	Employees per square kilometer of area of analysis
RRMILE	Railroads	Kilometers of railroad track per square kilometer of area of analysis
OZONED	Office Zoning	*
PEAK	Peak Flow	*
DUACRE	House Density	Dwelling units per square kilometer of area of analysis
IZONED	Industrial Zoning	*
POPDIF	Population Growth	*
VACOFF	Office Vacancy	*
AIRPRT	Airport Distance	Kilometers
OFFJOB	Office Employees	Employees per square kilometer of area of analysis
EMPOP	Employee Ratio	*
UNEMP	Unemployment	*
PERCAP	Future Income	*
GOVT	Government	*
RECAP	Collection Reserve	*
CROSS	Interceptor Density	Kilometers of interceptor pipe per 10,000 square meters of area of analysis
POOR	Poverty	*
LIMITS	Onsite Restrictions	*
PERCHG	County Growth	*
COST	Sewer Costs	*
CAPAC2	Treatment Capacity	*
VACHSE	Vacant Houses	*
INTDEN	Interchange Density	*
RZONED	Residential Zoning	*
CAPCHG	Income Growth	*
HOSCHG	Hospital Growth	*
HSECHG	Housing Growth	*
TLIMIT	Restriction Years	*
PHASE	Phasing	*
TRANS	Transit Stops	*
DISCBD	CBD Distance	Kilometers
vacdev	Vacant Developable	Square meters
vacund	Vacant Undevelopable	Square meters
AREA	Area of Analysis	Square meters
price	Median Price	*
median	Median Income	*

* Same as English units.

TABLE C-3 (CONTINUED)

METRIC UNITS OF VARIABLES USED IN THE PREDICTIVE EQUATIONS AND WORKSHEETS

Variable Names		
Predictive Equations	Worksheets	Metric Units
CAPAC1	Collection Capacity	*
manemp+	Manufacturing Workers	*
acre	Tract Area	Square kilometers
autoco	Drivers	*
county	County Area	Square kilometers
area5k	Sewered Land	Square meters
sch60+	School Kids	*
du60	Dwelling Units	*
intchg	Limited Access	*
remp1+	Current Employment	*
remp2+	Future Employment	*
SMArea	SMSA Area	Square kilometers
rail	Track	Kilometers
ozone	Zoned Office	Square meters
izone	Zoned Industrial	Square meters
smoff+	Office Workers	*
rpop2+	Future Population	*
LENGTH	Interceptors	Kilometers
totcst	Project Cost	*
fedcst	Federal Funds	*
pi1	Index One	*
pi2	Index Two	*
popcom	Population Served	*
ctyacc	County Interchanges	*
rzone	Zoned Residential	Square meters
per60	Current Income	*
rhosp1+	Current Medicals	*
rhosp2+	Future Medicals	*
rhse1+	Current Houses	*
rhse2+	Future Houses	*

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*Same as English units.

+Units for Predictive Equation variable are in 100s while units for Worksheet variables are in 1s.

APPENDIX D

GRAPHS OF ACTUAL VERSUS PREDICTED LAND USE FOR THE CROSS-VALIDATION ANALYSIS

1. **RES Equation**

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LINE   13          PRINCETON UNIVERSITY              *   TSP   *        VERSION OF AUGUST, 1969        PAGE    9



                                        PLOT OF ACTUAL(*) AND FITTED(+) VALUES                   PLOT OF RESIDUALS(O)

                                                                                           RESIDUAL
ID     ACTUAL        FITTED                                                                                 0.0
                                                                                          -.101E+04       .   0.       .
  4    5911.         6919.                      + +
                                         ----------------------------------------------------------
                                                                                           .172E+04       .   .   0    .
  8    9706.         7983.                          +    +                                -.350E+04       0   .        .
  9    .1197E+05     .1547E+05                                 +        +
                                         ----------------------------------------------------------
                                                                                     .     .962E+04       .   .        .          0
 11    .2357E+05     .1374E+05                                     +
                                         ----------------------------------------------------------
                                                                                           35.4           .   0        .
 15    6072.         6033.                      +                                         -.740E+04 0     .   .        .
 16    3745.         .1114E+05            +                     +                          771.           .   .0       .
 17    9709.         8938.                              + +
                                         ----------------------------------------------------------
                                                                                          -.695E+04  0    .   .        .
 19    5100.         .1205E+05                 +                  +                        .113E+04       .   . 0      .
 20    7540.         6407.                         + +
                                         ----------------------------------------------------------
                                                                                           .356E+04       .   .       0.
 22    5017.         1461.               +         +
                                         ----------------------------------------------------------
                                                                                           .397E+04       .   .        0
 23    7372.         3406.                  +           +
                                         ----------------------------------------------------------
                                                                                           .543E+04       .   .        . 0
 25    5903.         469.3             +                +
                                         ----------------------------------------------------------
                                                                                           .127E+04       .   . 0      .
 28    4626.         3351.                  +   +
                                         ----------------------------------------------------------
                                                                                           .206E+04       .   .  0     .
 31    7772.         5713.                       +     +
                                         ----------------------------------------------------------
                                                                                          -287.           .   0        .
 33    6516.         6803.                         ++
                                         ----------------------------------------------------------
                                                                                           134.           .   0        .
 34    .1358E+05     .1344E+05                                     +                      -.362E+04       0   .        .
 35    .1050E+05     .1412E+05                              +        +                    -.434E+04      0.   .        .
 36    369.0         4711.             +          +                                       -.139E+04       . 0 .        .
 37    .1322E+05     .1461E+05                                    +   +
                                         ----------------------------------------------------------
                                                                                           .171E+04       .   .  0     .
 39    5375.         3670.                 +    +
```

2. COMM Equation

```
    LINE   14          PRINCETON UNIVERSITY                 *  TSP    *          VERSION OF AUGUST, 19[illegible]                PAGE   1[illegible]



                                      PLOT OF ACTUAL(*) AND FITTED(+) VALUES                     PLOT OF RESIDUALS(O)

ID     ACTUAL       FITTED                                                          RESIDUAL
                                                                                                         0.0
   4    892.4        1438.          *  +                                             -546.           .   0.    .
                                   ---------------------------------------------
   8    1794.        2657.              *   +                                        -873.           .  0 .    .
   9    1206.        250.8          +   *                                             955.           .    . 0  .
                                   ---------------------------------------------
  11    3862.        191.6        +               *                                   .367E+04       .    .    .    0
                                   ---------------------------------------------
  15    1118.        1169.           **                                              -71.2           .    0    .
  16    1104.        2251.           *    +                                          -.119E+04       . 0  .    .
  17    2027.        251.4          +      *                                          .178E+04       .    .   0.
                                   ---------------------------------------------
  19    701.9        4336.          *              +                                 -.363E+04  0    .    .    .
  20    2776.        5693.                   *            +                        -.292E+04    0  .    .    .
                                   ---------------------------------------------
  22    1897.        178.2        +       *                                           .172E+04       .    .   0.
                                   ---------------------------------------------
  23    1640.        1870.              **                                           -230.           .   0.    .
                                   ---------------------------------------------
  25    774.0        2373.          *      +                                         -.160E+04       .0   .    .
                                   ---------------------------------------------
  28    722.8        1379.          *  +                                             -656.           .  0 .    .
                                   ---------------------------------------------
  31    1197.        2596.            *     +                                        -.140E+04       .0   .    .
                                   ---------------------------------------------
  33    807.8        537.4         +*                                                 270.           .    .0   .
                                   ---------------------------------------------
  34    1071.        -133.8     +    *                                                .120E+04       .    . 0  .
  35    .1127E+05    6266.                                      +                     *   .500E+04       .    .    .       0
  36    245.7        -37.05     + *                                                 283.           .    .0   .
  37    1510.        1950.             * +                                         -441.           .   0.    .
                                   ---------------------------------------------
  39    609.2        1605.         *   +                                             -596.           . 0  .    .
```

3. OFFICE Equation

```
         LINE   15           PRINCETON UNIVERSITY                  *   TSP    *          VERSION OF AUGUST, 1969              PAGE    15



                                            PLOT OF ACTUAL(*) AND FITTED(+) VALUES                        PLOT OF RESIDUALS(0)

     ID     ACTUAL        FITTED                                                            RESIDUAL
                                                                                                                   0.0
      4      86.40         468.1             *       +                                        -382.          . 0    .       .
                                         ------------------------------------------------
      8      288.5         914.7                  *             +                             -626.        0 .      .       .
      9      555.1         1009.                       *          +                           -454.          .0     .       .
                                         ------------------------------------------------
     11      687.5        -214.4      +                    *                                   902.          .      .       .     0
                                         ------------------------------------------------
     15      935.9         648.9                          +     *                              287.          .      .    0  .
     16      403.4         647.7                     *    +                                   -244.          .   0  .       .
     17      822.3         161.0               +              *                                661.          .      .       .  0
                                         ------------------------------------------------
     19      995.9         1000.                                 *+                           -4.31          .      0       .
     20      230.9         844.7                *             +                               -614.        0 .      .       .
                                         ------------------------------------------------
     22      177.8         287.5               *  +                                           -110.          .    0 .       .
                                         ------------------------------------------------
     23      34.00         210.7            *   +                                             -177.          .    0 .       .
                                         ------------------------------------------------
     25      94.70         655.8              *           +                                   -561.         0.      .       .
                                         ------------------------------------------------
     28      144.6         393.9               *     +                                        -249.          .  0   .       .
                                         ------------------------------------------------
     31      577.2         681.8                         * +                                  -105.          .     0.       .
                                         ------------------------------------------------
     33      385.5         515.2                     * +                                      -130.          .    0 .       .
                                         ------------------------------------------------
     34      296.6         1065.                   *                +                         -768.      0   .      .       .
     35      2111.         1312.                                         +                 *   799.          .      .       .     0
     36      94.60         64.15             +*                                                30.4          .      0       .
     37      489.7         681.7                       *   +                                  -192.          .   0  .       .
                                         ------------------------------------------------
     39      98.60         110.7               +                                              -12.1          .      0       .
```

4. MANF Equation

```
LINE   16          PRINCETON UNIVERSITY                *  TSP  *          VERSION OF AUGUST, 1975             PAGE   1


                                     PLOT OF ACTUAL(*) AND FITTED(+) VALUES                   PLOT OF RESIDUALS(O)


ID     ACTUAL       FITTED                                                          RESIDUAL
                                                                                                       0.0
   4    1785.        1717.              **                                          67.9           .    0    .
                                  --------------------------------------------
   8    1050.        1090.           +                                             -39.4           .    0    .
   9    514.2        2108.         *      +                                        -.159E+04       . 0  .    .
                                  --------------------------------------------
  11    736.8        1103.          * +                                            -366.           .   0.    .
                                  --------------------------------------------
  15    1071.        1205.           **                                            -134.           .   0.    .
  16    3265.        3332.                     +                                   -66.8           .    0    .
  17    553.4        435.1         +                                                116.           .    0    .
                                  --------------------------------------------
  19    1426.        4755.             *             +                             -.333E+04     0 .    .    .
  20    4859.        4363.                         + *                              496.           .    .0   .
                                  --------------------------------------------
  22    1271.        156.4       +    *                                             .111E+04       .    . 0  .
                                  --------------------------------------------
  23    2365.        177.2       +         *                                        .219E+04       .    .    0
                                  --------------------------------------------
  25    359.2        2727.        *          +                                     -.237E+04       0    .    .
                                  --------------------------------------------
  28    1044.        344.9        +  *                                              700.           .    .0   .
                                  --------------------------------------------
  31    1154.        1313.            +                                            -158.           .   0.    .
                                  --------------------------------------------
  33    1311.        1848.            *  +                                         -537.           .   0.    .
                                  --------------------------------------------
  34    517.7        5971.         *                       +                       -.545E+04  0    .    .    .
  35    .1066E+05    3865.                        +                             *   .680E+04       .    .    .      0
  36    335.5        51.18       **                                                 284.           .    0    .
  37    4542.        2259.                 +         *                              .228E+04       .    .    0
                                  --------------------------------------------
  39    140.8       -363.1     + *                                                  504.           .    .0   .
```

5. HIWAYS Equation

```
    LINE   17           PRINCETON UNIVERSITY                 *   TSP   *           VERSION OF AUGUST. 1969             PAGE   21


                                       PLOT OF ACTUAL(*) AND FITTED(+) VALUES                      PLOT OF RESIDUALS(0)

ID     ACTUAL        FITTED                                                           RESIDUAL                    0.0
    4   15.40        8.726          + *                                                  6.67               .      . 0     .
                                    -----------------------------------------------
    8   47.00        48.93                             *+                                 -1.93               .      0       .
    9   84.00        114.9                                               *              +   -30.9               .0     .       .
                                    -----------------------------------------------
   11   57.50        38.66                       +        *                              18.8               .      .   0   .
                                    -----------------------------------------------
   15   56.60        53.74                              *+                               2.86               .      .0      .
   16   42.30        68.18                        *            +                        -25.9               . 0    .       .
   17   25.30        37.00                 *    +                                       -11.7               .    0 .       .
                                    -----------------------------------------------
   19   3.000        62.94       *                          +                           -55.9        0      .      .       .
   20   15.20        80.00            *                             +                   -64.8       0       .      .       .
                                    -----------------------------------------------
   22   45.60        31.15                   +      *                                    14.4               .      .  0    .
                                    -----------------------------------------------
   23   13.40        19.50           *  +                                               -6.10               .     0.       .
                                    -----------------------------------------------
   25   30.30        70.56                   *                  +                       -40.3              0.      .       .
                                    -----------------------------------------------
   28   30.80        40.50                   *   +                                      -5.70               .    0 .       .
                                    -----------------------------------------------
   31   48.30        53.30                           * +                                -5.00               .     0.       .
                                    -----------------------------------------------
   33   34.50        76.19                     *                  +                     -41.7            0  .      .       .
                                    -----------------------------------------------
   34   24.80        105.9                *                                    +        -81.1    0          .      .       .
   35   48.20        64.83                           *      +                           -16.6               .  0   .       .
   36   14.00        21.67           *  +                                               -7.67               .     0.       .
   37   36.50        41.14                      * +                                     -4.64               .     0.       .
                                    -----------------------------------------------
   39   15.50        5.484       +    *                                                  10.4               .      . 0     .
```

6. <u>EDUC Equation</u>

```
LINE   18          PRINCETON UNIVERSITY             *  TSP  *           VERSION OF AUGUST, [illegible]          PAGE   24


                                              PLOT OF ACTUAL(*) AND FITTED(+) VALUES                         PLOT OF RESIDUALS(0)

                                                                                                  RESIDUAL
 ID    ACTUAL      FITTED                                                                                            0.0
   4    454.0       488.2                             *  +                                          -34.2      .       0.      .
                                 ------------------------------------------------------------
   8    635.8       694.8                                       *  +                                -59.0      .     0  .      .
   9    724.0       747.4                                           *+                              -23.4      .       0.      .
                                 ------------------------------------------------------------
  11    984.8       218.6                      +                                      *              766.      .        .      .               0
                                 ------------------------------------------------------------
  15    350.8       652.5                             *              +                              -302.      0.       .      .
  16    499.5       408.0                                 +   *                                      91.5      .        .  0   .
  17    982.5       1108.                                                              *     +        -126.      .    0   .      .
                                 ------------------------------------------------------------
  19    368.6       440.9                             *   +                                          -72.3      .      0 .      .
  20    1279.       896.0                                                       +                  * 383.      .        .      .   0
                                 ------------------------------------------------------------
  22    707.3       489.7                                  +          *                              218.      .        .      0
                                 ------------------------------------------------------------
  23    655.0       320.7                        +                 *                                 334.      .        .      .  0
                                 ------------------------------------------------------------
  25    359.2       456.4                             *   +                                          -97.2      .      0 .      .
                                 ------------------------------------------------------------
  28    715.5       863.8                                        *       +                          -148.      .  0     .      .
                                 ------------------------------------------------------------
  31    662.5       690.1                                     *+                                     -27.6      .       0.      .
                                 ------------------------------------------------------------
  33    643.7       630.7                                   *                                         13.0      .         0     .
                                 ------------------------------------------------------------
  34    1037.       895.5                                                      +     *                 141.      .        .    0 .
  35    457.6       460.7                                  *                                         -3.11      .         0     .
  36    95.50      -41.56       +      *                                                             137.      .        .    0 .
  37    615.5       804.4                                       *        +                          -189.      .   0    .      .
                                 ------------------------------------------------------------
  39    11.60       109.6          *     +                                                           -98.0      .      0 .      .
```

D-7

7. REC Equation

```
    LINE   19          PRINCETON UNIVERSITY               *   TSP    *         VERSION OF AUGUST, 1969             PAGE   27

                                     PLOT OF ACTUAL(*) AND FITTED(+) VALUES                     PLOT OF RESIDUALS(0)

ID     ACTUAL       FITTED                                                         RESIDUAL                    0.0
   4    28.00        108.1         *   +                                            -80.1                 .  0  .      .
                                  --------------------------------------------
   8    37.00        184.5          *      +                                        -147.                 .0    .      .
   9    437.0        930.6                              *                        +  -494.     0           .     .      .
                                  --------------------------------------------
  11    500.0        547.9                                 *  +                     -47.9                 .    0.      .
                                  --------------------------------------------
  15    13.00        292.8        *             +                                   -280.            0   .     .      .
  16    103.0        263.1             *       +                                    -160.                 .0    .      .
  17    106.0        193.2             *    +                                       -87.2                 .  0  .      .
                                  --------------------------------------------
  19    444.0        362.9                          +   *                            61.1                 .     .  0   .
  20    289.0        401.6                      *     +                             -113.                 . 0   .      .
                                  --------------------------------------------
  22    65.00       -35.56      +    *                                               101.                 .     .   0  .
                                  --------------------------------------------
  23    230.0        129.3              +    *                                       101.                 .     .   0  .
                                  --------------------------------------------
  25    382.0        432.1                           *  +                           -50.1                 .    0.      .
                                  --------------------------------------------
  28    62.00        93.51           * +                                            -31.5                 .    0.      .
                                  --------------------------------------------
  31    247.0        292.9                    *   +                                 -45.9                 .    0.      .
                                  --------------------------------------------
  33    98.00        229.2              *     +                                   -131.                 . 0   .      .
                                  --------------------------------------------
  34    193.0        314.9                   *     +                                -122.                 . 0   .      .
  35    203.0        680.7                   *                       +              -478.       0         .     .      .
  36    19.00        140.4         *     +                                          -121.                 . 0   .      .
  37    215.0        76.13            +      *                                       139.                 .     .    0 .
                                  --------------------------------------------
  39    129.0        60.81           +  *                                            68.2                 .     .   0  .
```

8. WHOLE Equation

```
    LINE   20          PRINCETON UNIVERSITY               *   TSP   *          VERSION OF AUGUST, 19[illegible]           PAGE   32



                                     PLOT OF ACTUAL(*) AND FITTED(+) VALUES                    PLOT OF RESIDUALS(O)

ID     ACTUAL       FITTED                                                        RESIDUAL
                                                                                                      0.0
   4    74.30        389.2                 *     +                                 -315.       . 0     .      .
                                  --------------------------------------------
   8    182.3        17.65                +  *                                      165.       .       .  0   .
   9    937.6        1156.                                   *   +                 -219.       .  0    .      .
                                  --------------------------------------------
  11    312.5       -165.6            +         *                                   478.       .       .      . 0
                                  --------------------------------------------
  15    333.7       -11.39               +      *                                   345.       .       .     0.
  16    432.9        563.2                        *  +                             -130.       .    0  .      .
  17    .0           108.5               *  +                                      -109.       .     0 .      .
                                  --------------------------------------------
  19    425.0        652.7                        *    +                           -226.       .  0    .      .
  20    1871.        1099.                                                  +               *   772.       .       .      .      0
                                  --------------------------------------------
  22    1399.        672.5                             +              *             726.       .       .      .     0
                                  --------------------------------------------
  23    300.6        576.9                      *    +                             -276.       . 0     .      .
                                  --------------------------------------------
  25    646.0        322.7                      +      *                            323.       .       .     0.
                                  --------------------------------------------
  28    361.4        511.5                       *  +                              -150.       .    0  .      .
                                  --------------------------------------------
  31    570.4        53.89                +          *                              517.       .       .      . 0
                                  --------------------------------------------
  33    671.0        953.5                             *     +                     -282.       . 0     .      .
                                  --------------------------------------------
  34    156.5        382.3                   *   +                                 -226.       .  0    .      .
  35    256.5        769.9                     *         +                         -513.     0 .       .      .
  36    9.300        257.0                *    +                                   -248.       .  0    .      .
  37    732.1        547.2                           +  *                           185.       .       .  0   .
                                  --------------------------------------------
  39    10.90       -500.8     +          *                                         512.       .       .      . 0
```

9. OTHER Equation

```
    LINE   21          PRINCETON UNIVERSITY                    *   TSP   *          VERSION OF AUGUST, 1969          PAGE   33



                                     PLOT OF ACTUAL(*) AND FITTED(+) VALUES                   PLOT OF RESIDUALS(0)

ID      ACTUAL        FITTED                                                            RESIDUAL
                                                                                                              0.0
   4    486.1        100.1           +       *                                     386.                  .     .  0 .
                                  --------------------------------------------
   8    308.8        116.4            +  *                                         152.                  .     .0   .
   9    603.7        680.0                     *+                                 -76.3                  .    0.    .
                                  --------------------------------------------
  11    763.6        446.1                  +     *                                317.                  .     . 0  .
                                  --------------------------------------------
  15    866.2        586.9                     +    *                              277.                  .     . 0  .
  16    377.0        842.2                 *       +                              -465.                  . 0   .    .
  17    434.4        133.8            +     *                                      301.                  .     . 0  .
                                  --------------------------------------------
  19    268.7        1174.              *                 +                       -505.                0 .     .    .
  20    558.5        1510.                    *                 +                 -552.                0 .     .    .
                                  --------------------------------------------
  22    532.6        159.9            +      *                                     373.                  .     .  0 .
                                  --------------------------------------------
  23    82.20        117.1           *+                                           -34.9                  .    0.    .
                                  --------------------------------------------
  25    389.8        1233.                 *               +                      -843.                 0.     .    .
                                  --------------------------------------------
  28    274.6        510.2               *   +                                    -236.                  .  0  .    .
                                  --------------------------------------------
  31    414.0        940.8                 *         +                            -527.                  .0    .    .
                                  --------------------------------------------
  33    282.9        605.6               *     +                                  -323.                  . 0   .    .
                                  --------------------------------------------
  34    146.9        2343.            *                                         + -.220E+04 0            .     .    .
  35    316.7        724.3               *       +                                -408.                  . 0   .    .
  36    58.30       -227.4     +    *                                              286.                  .     . 0  .
  37    1016.        220.0              +              *                           796.                  .     .    .0
                                  --------------------------------------------
  39    45.40        61.86          *+                                            -16.5                  .    0.    .
```

APPENDIX E

SUPPLEMENTARY INFORMATION

Thomas McCurdy
EPA Project Officer

I. General

The EPA Technical Committee mentioned in the Acknowledgements on p. iii included the following personnel:

Martha Burke	Office of Transportation and Land Use Policy
J. David Foster	Control Programs Development Division, OAQPS
Walter Issac	Municipal Construction Division, OWPO
Thomas H. Pierce	Office of Land Use Coordination
John L. Robson	Strategies and Air Standards Division, OAQPS
David Sanchez	Control Programs Development Division, OAQPS
Carol Wegrzynowicz	Municipal Construction Division, OWPO

OAQPS stands for Office of Air Quality Planning and Standards and OWPO means Office of Water Program Operations.

A number of Technical Committee members reviewed a draft of this report. A consensus comment was that a number of items were not fully explained in the contractor's text. Thus, the purpose of this appendix, written by the EPA Project Officer, is to supply needed supplementary information. The material is organized around the worksheets. Information is presented on the following topics:

1. how to obtain input variables for the predictive model (Worksheet 1).
2. how to estimate the sensitivity of the model to changes in input variables (related to Worksheet 1).
3. how to distribute predicted land use within the area of analysis (related to Worksheet 2).
4. how to estimate residential and commercial breakdowns (Worksheets 3 and 4).

II. Simplifying the Analysis and Obtaining Input Data

To use the nine predictive (Worksheet 2) and six disaggregated (Worksheet 4) equations requires the user to come up with values for 52 variables. (Additional input data are required for VMT and emissions prediction equations). Some datum will be easy to obtain because it is available from the wastewater treatment facility owner or operator; this is particularly true of "major project" variables, such as collection system capacity and peak flow. Other data may be difficult to obtain, especially non-OBERS future year socio-economic data. It is the purpose of this Section to provide some help on how a user can obtain needed input data. A simplifying procedure is also provided to reduce user effort to a minimum. This procedure, however, correspondingly reduces the amount of confidence that can be placed in GEMLUP predictions. Using the full-blown analysis allows the user to say that there is a 90 percent probability that the predicted land uses will be within ± (x) percent of their true value (the percentages being obtained from optional Worksheet 5 as a confidence interval). If any short-cut procedure is used, on the other hand, nothing can be said about the confidence level of a prediction. The tradeoff in using a simplified procedure is between time and rigor. Only a user can decide which is more important in his or her situation.

Because many input variables are used in more than one predictive or disaggregation equation, the number of input variables required varies with the combination of predictive equations used. Although there are numerous ways to combine the 9 land use predictive equations, there is one way that is preferred. The preferred order of land uses is:

1. residential
2. manufacturing
3. commercial
4. office-professional
5. highways
6. education
7. wholesale
8. other
9. recreation

Something should probably be said about highways being placed fifth in the list. The causal analysis (Volume I) confirmed that Highways is an important land use in inducing other development. A question may arise, then, in the reader's mind concerning the reason why Highways is not ranked higher than fifth. The reason is that the above listing strikes a balance between theoretical importance and air pollution emissions importance -- for purposes of GEMLUP, highways do not have any direct emissions. Motor vehicular emissions due to vehicles using highways are accounted for in the VMT model and are not tied directly to the amount of highway land use. Therefore, from the viewpoint of an inventory for direct emissions, highways are an important land use.

To use the residential predictive equation requires that 12 input variables be obtained; of these, nine are considered to be sensitive and the remaining 3 variables are considered to be very sensitive. (The relative sensitivity of a variable depends upon how much it affects predicted output vis-a-vis other variables. This is discussed below under "sensitivity analysis." Note that all residential variables are defined to be sensitive because of the critical position that residential predictions play in subsequent analyses). If manufacturing predictions are made after residential predictions, only four additional variables are required. One of these is sensitive and another is very sensitive. Five of the variables obtained for residential predictions are also used in the manufacturing equation.

Marginal new information requirements for each equation, in the order listed above, are summarized in Table E-1. Also included are the disaggregated equations, listed in the only order that is logical. The first five land uses listed in E-1 are considered to be "core" uses that should be predicted for each application. The remaining land uses are considered to be of secondary importance both from an emissions (practical) and theoretical point of view.

Given the extensive data requirements of the secondary and disaggregated equations and the relative insensitiveness of their predictive land uses to air pollution emissions, it probably is not worth the effort to obtain data needed to use the equations if the analysis is being done solely to estimate area of analysis emissions. In this instance, a user can save a lot of time by just predicting core land uses and "scaling" secondary land uses from them by simple ratios. The ratios, found below in Table E-2, are developed from raw data obtained during GEMLUP case studies. They are based on mean values for the various land uses. "Redundant" ratios are provided so that more than one core land use can be used to estimate a particular secondary land use. The differing estimates could then be averaged to obtain a representative value.

To provide an example, suppose the residential predictive equation was used and it estimated that the area of analysis would have 10,000 dwelling units ten years after the waterwater facility of interest is constructed. Using the default ratios of Table E-2, approximately 710,000 ft^2 of educational building area might be expected (0.071 x 10,000 x 1,000). Suppose also that the manufacturing equation was used and it predicted that 2,000,000 ft^2 of manufacturing would exist in the area of analysis by the end of the 10 year period. Using the education-to-manufacturing default ratio of Table E-2

Table E-1

MARGINAL INPUT INFORMATION REQUIREMENTS TO RUN THE PREDICTIVE AND DISAGGRATED EQUATIONS

Land Use Type	# of New Input Variables Required	# of New Sensitive or Very Sensitive Variables	# of Previously Used Input Variables Required
CORE			
Residential	12	12	0
Manufacturing	4	2	5
Commercial	7	3	5
Office - Professional	2	0	6
Highways	2	0	6
SECONDARY*			
Education	8	1	4
Wholesale	4	3	5
Other	5	4	3
Recreation	4	3	4
DISAGGREGATED+			
% Single Family	4	1	6
% Multi-Family	3	0	4
% Two-Family	0	0	0
% Large Commercial	4	0	2
% Medium Commercial	3	0	4
% Small Commercial	0	0	0

Notes: *New variables are defined to be those not included in one or more of the core land use equations, regardless of whether or not the variable appears in a secondary land use equation.

+New variables are defined to be those not included either in one or more of the core land use equations or in one or more of the preceding disaggregated equations within the same class (i.e., residential and commercial).

Table E-2

DEFAULT RATIOS TO RELATE SECONDARY LAND USES TO CORE LAND USE TYPES

Variables	Ratio	Units[1]
. . . with RESIDENTIAL		
Education	0.071	1,000 ft^2/du
Wholesale	0.054	"
Other	0.052	"
Recreation	0.024	acres/du
Manufacturing	0.207	1,000 ft^2/du
Commercial	0.212	"
Office - Professional	0.058	"
Highways	0.005	lane miles/du
. . . with MANUFACTURING		
Education	0.367	1,000 ft^2/1,000 ft^2
Wholesale	0.264	"
Other	0.252	"
Recreation	0.115	acres/1,000 ft^2
... with COMMERCIAL		
Education	0.359	1,000 ft^2/1,000 ft^2
Wholesale	0.258	"
Other	0.246	"
Recreation	0.112	acres/1,000 ft^2
. . . with OFFICE - PROFESSIONAL		
Education	1.317	1,000 ft^2/1,000 ft^2
Wholesale	0.948	"
Other	0.903	"
Recreation	0.413	acres/1,000 ft^2

Note: Abbreviations used in the units are:

ft^2 = square feet
du = dwelling unit (housing unit)

Note that the unit given as 1,000 ft^2/1,000 ft^2 could be stated as ft^2/ft^2. The first choice is shown because it has the same dimensions as the land use prediction equations (Worksheet 3).

results in an estimate of 734,000 ft^2 of educational building area (0.367 x 2,000 x 1,000). Averaging the two estimates gives a "best-guess" prediction of 722,000 ft^2 of educational building area.

Default value percentages for the two disaggregated land uses, residential and commercial, are presented in Table E-3. While the estimates represent mean values for the 40 cases used in GEMLUP, local data should be used wherever possible. Since the data are relatively easy to obtain, particularly for residential, the effort probably will be well worth it.

To use the disaggregated estimates, simply multiply the decimal equivalent of the percentage value shown in Table E-3 by the predicted value "output" by the commercial equation of Worksheet 2 multiplied by the area of analysis/10,000 acres factor needed to convert density figures to totals. Suppose, for example, that the Worksheet 2 commercial prediction is 2,000 x 10^3 ft^2/10,000 acres and the area of analysis is 20,000 acres. The factor is therefore 20,000 acres divided by 10,000 or 2 (forget its units: the figure essentially represents the number of 10,000 acres parcelsper area of analysis). Multiplying 2,000 x 10^3 ft^2 by 2 gives 4,000,000 ft^2 of commercial development building area within the area of analysis as the predicted value. Using the default percentages of Table E-3 results in the following breakdown by size of commercial establishment. 428,000 ft^2 of large commercial, 420,000 ft^2 of medium commercial, and 3,152,000 of small commercial (4 x 10^6 times 0.788).

If the user is going to predict with core equations and derive secondary and disaggregated land uses from them, only the variables listed in Table E-4 will have to be obtained as inputs to Worksheet 1. The variables appear in the order shown on Table 2-5 (p. 2-20). There are now 27 variables that have to be obtained instead of the original 52 listed in Table 2-5. That table should be consulted for a full description of the variables.

Table E-3

DEFAULT PERCENTAGES FOR DISAGGRATED LAND USES

Land Use	% of Total Land Use in the Category
Single Family Detached	73.5
Multi-Family	10.6
Two Family[1]	15.9
Subtotal	100.0
Large Commercial[2]	10.7
Medium Commercial[3]	10.5
Small Commercial[4]	78.8
Subtotal	100.0

Notes: [1] Included are single-family attached, single family quadplexes, and the like

[2] Commercial development with floor area > 100,000 ft^2

[3] Commercial development with floor area between 50,000 and 100,000 ft^2

[4] Commercial development with floor area < 50,000 ft^2

Table E-4

LIST OF VARIABLES NEEDED TO PREDICT CORE LAND USES

Variable	Equation(s)
County Area	Residential
Vacant Developable	Residential, Manufacturing, Commercial
Vacant Undevelopable	Residential, Manufacturing, Commercial
Zoned Office	Manufacturing, Office-Professional
Zoned Industrial	Office-Professional
Limited Access	Commercial
Population Growth	Office-Professional
Office Vacancy	Manufacturing
Median Price	Residential, Highways
Future Employment	Commercial
Airport Distance	Manufacturing
Track	Manufacturing, Office, Highways
Area of Analysis	All Core Equations
Sewered Land	Commercial
Interceptors	Highways
Collection Capacity	Residential, Commercial, Highways
Peak Flow	Residential, Commercial, Office - Professional, Highways
SMSA Area	Commercial
Tract Area	Residential, Manufacturing, Commercial
Dwelling Units	Commercial, Office-Professional
School Kids	Commercial
Nonmobility	Residential
Median Income	Residential, Highways
Government	Highways
Current Employment	Commercial
Manufacturing Workers	Residential, Manufacturing
Drivers	Residential

III. Obtaining Needed Input Variables for Worksheet 1

Input data must be obtained for variables listed in Table 2-5 in order to use all of the predictive equations. Basically, data are needed for three time periods (time of wastewater facility completion, t, and five and ten years after that (t+5 & t+10) and four geographical area (area of anlysis, census tract(s) most representative of the area of analysis, county, and SMSA). Because t itself will most likely be in the future, there is a problem of getting values for these supposedly current time period variables. The material to follow is designed to help solve this problem. The areal issue will be discussed first.

The area of analysis is the legal service area of the wastewater treatment facility. It generally includes only one watershed, but may include contiguous areas whose sewage is conveyed to the natural drainage basin by some mechanical means. Data needed for the area of analysis is entirely "physical" such as geographical area, vacant undevelopable land, and amount of zoned residential land. These data mostly come from maps.

Census tract socio-economic data are required. These data come from the U.S. Bureau of Census's Census of Population and Housing:Census Tract series. Updating this information will have to be done; some guidance on doing it appears below. If the area of analysis is not tracted, municipality-level data are substituted for census tract data. In that case, the data come from the Census of Population and the Census of Housing: Metropolitan Housing Statistics. Again, the data will have to be updated.

The user will have to decide what census tract(s) are to be used. A rule-of-thumb is to use census tracts that represents the area of analysis most closely. This simple rule is difficult to apply in practice, as there are a large number of circumstances possible, such as the area of analysis is:

1. fully tracted (in one or more municipalities).
2. partially tracted, with the remaining area in another municipality (which itself may be tracted).
3. untracted in an incorporated area.
4. untracted in an unincorporated area.

By far the most common circumstance encountered during GEMLUP data gathering is the first case -- the area of analysis was fully tracted. Often, however, a number of municipalities were involved (or one municipality and tracted areas in the county). This situation is depicted in Figure E-1.

Required census tract socio-economic data would definitely be obtained for the following census tracts: 4 to 6 and 8. Less than half of census tracts 1 and 9 are within the area of analysis, so they would not be used. Whether data for census tract 2 would be used or not depends upon the situation. If most of the people living in the tract are located within the area of analysis or if population is distributed evenly throughout the census tract, the tract should be used.

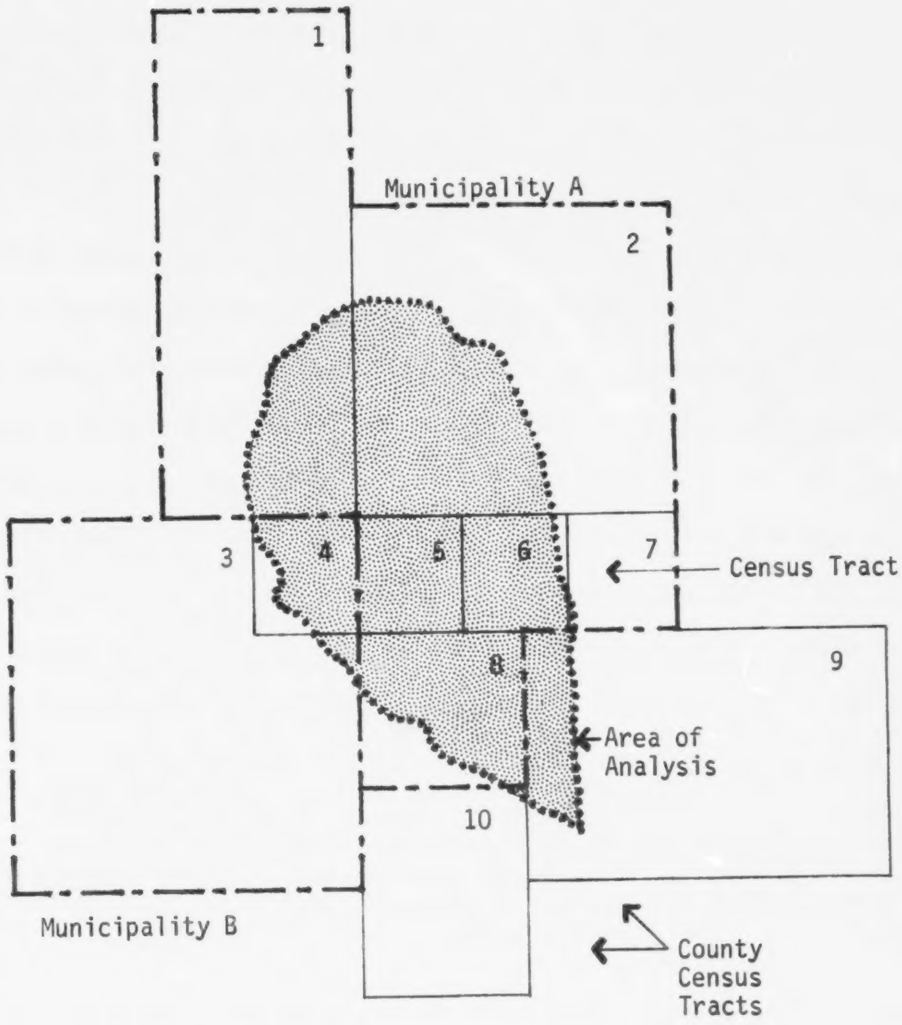
Note that just about all socio-economic variables are used on a per unit area basis (or are relative variables to begin with; i.e., are percentage variables). This is true for all census tract variables, which means that non-relative census tract data are divided by tract area to derive the per unit area (density) variable used in GEMLUP predictive equations. Examples are:

1. Manufacturing Density, or manufacturing employment divided by census tract area.
2. House Density, or the number of housing units divided by census tract area.

Census tract area will have to be obtained directly off of the maps included in the SMSA Census Tract report (with a planimeter preferably) if the data are

Figure E-1

HYPOTHETICAL EXAMPLE OF A FULLY-TRACTED AREA OF ANALYSIS


1
Municipality A
2
3
4
5
6
7
Census Tract
8
9
Area of Analysis
10
Municipality B
County Census Tracts

not already available. Many city and regional planning agencies have census tract area data because of its use in transportation and housing plan development. These agencies should be checked first for the area data.

Area information is also required for the municiaplity (but only if census tracts are not used), the county, and the SMSA. Area information for these jurisdictions are most easily found in the latest County and City Data Book. The information is also contained in the Census of Population.

We turn now to the problem of obtaining estimates for variables in the future. As mentioned in the opening paragraph of this section, basically three time periods are involved: t, when the project "opens," t+5, five years after t, and t+10, or ten years after the project opens. As we shall discuss below, there probably will not be a good source of data (certaintly no single source) for all variables for the needed time period, since t and t + 10 could be any year and projected data are often only done for decennial or, at best, quinquennial periods. Consequently, data available will have to be manipulated to obtain needed values. Some assistance follows on how this can be done for each variable listed in Table 2-5.

1. County Area: area of the county in square miles for time t (and t + 5). This variable does not change, except for minor, infrequent boundary adjustments. Use the value in the latest County and City Data Book or other Census material, or obtain it from the county or regional planning agency. This variable is required in the Residential equation, so it must be obtained even if the simplified predictive approach is used. It is a "sensitive" variable.

2. Vacant Developable: vacant developable acreage in the area of analysis (area) in time t. This variable and the next, vacant Undevelopable, are related by the following simple relation:

(1)		(2)		(3)		(4)
Total Area Acreage$_t$ (Area of Analysis)	=	Developed Area Acreage$_t$	+	Vacant Developable Area Acreage$_t$	+	Vacant Undevelopable Area Acreage$_t$

Because it is probably easier to get estimates for variables 1,2 and 4, vacant developable can be obtained as a residual. The fact that time t will be in the future and that variables 1 and 4 do not change over time, means that vacant developable is most easily obtained by estimating developed area acreage (2) for time t and substracting it from the quanity $\left[(1) - (4)\right]$. (How 1 and 4 are obtained is explained later.)

Developed area acreage for time t is estimated from developed area coverage for a current or past time period (t') updated by some proportionality factor. Development in time t' is obtained from aerial photographs (as was done in GEMLUP case studies), or from existing land use maps or other planning studies. The portionality factor applied to development in time t' that intuitively makes a lot of sense is a population/density ratio of the form:

$$\frac{\underset{\text{(estimated)}}{\text{population}_t} \quad - \quad \underset{\text{(known)}}{\text{population}_{t'}}}{\underset{\text{(estimated)}}{\text{family size}_t} \quad \bullet \quad \underset{\text{(estimated)}}{\text{housing unit density}_t}}$$

This ratio is called the "factor" in subsequent discussion. The simple formula for developed acreage becomes:

$$\text{Developed Area Acreage}_t = \text{Developed Area Acreage}_{t'} + \text{Factor (Acres)}$$

The factor is trend related as it includes future residential density and family size (in time t), which might change from the base year (t'). However, since the time difference between t and t' will probably never be greater than 10 years, most likely there will not be a big change in the variables in question for the $t' \longrightarrow t$ time period.

Population of the area of analysis in times t and t' must be obtained. Because the area of analysis will probably not be the same as a census area, population data must be apportioned somehow. (Population$_t$ will probably be provided in the facility plan documentation, but is assumed not to be available for this discussion.) There are a number of ways to apportion population data and a number of places where the information could come from. Census block and tract data could be apportioned to the area of analysis, if available, to estimate population in time t'. The past annual population change rate could then be used to estimate population in time t. Traffic zone data may also be used for this purpose, as may watershed-based pouplation projections, if available.

Because there are a lot of possibilities, it is not possible to cover them all here. Local and regional planners deal with this issue a lot; they should be able to provide assistance in population apportionment.

A numercial example using the factor should clarify the procedure and tie loose ends together. Population in time t' is estimated to be 10,000. It was apportioned from census tract and block data. Developed land associated with this population is about 2,500 acres (@ 4 housing units per acre). Population_t is estimated to be 20,000; this figure comes from the facility plan. Family size_t is thought to be 3.1 persons per family (actually 3.1 persons per housing unit), which is the latest estimate of family size available from the regional planning agency. It is not expected to change between now and t. $\text{Housing unit density}_t$ is expected to be about 4.5 units per acre based on recent development trends.

Substituting the above into the formula for developed area acreage_t gives:

$$\text{Developed Area Acreage}_t = 2{,}500 \text{ acres} + \left[\frac{(20{,}000 - 10{,}000) \text{ people}}{3.1 \frac{\text{people}}{\text{unit}} \cdot 4.5 \frac{\text{units}}{\text{acre}}} \right]$$

$$= 2{,}500 \text{ acres} + 717 \text{ acres}$$

$$= 3{,}217 \text{ acres}$$

This value would be subtracted from the known quantity of (area of analysis) minus (vacant undevelopable area) to obtain Vacant Developable.

A totally different tack could be taken to come up with estimates of vacant developable land. This method is also based on estimating developed land in some past or current time t', but is more direct. It simply entails determining how much land is being subdivided annually in the area of analysis and multiplying it by the time period (t - t').

For example, say that 23 acres of land are being developed annually in the area of analysis -- on average, and this rate is expected to remain pretty constant. For an 8 year period, this means that 184 acres will be developed. This has to be added to the already developed acreage to get total developed land in time t. The subtractions mentioned above would be required to get Vacant Developable.

Vacant Developable is used in the Residential and two other "core" predictive equations. It is a sensitive variable.

3. Vacant Undevelopable: vacant and undevelopable acreage in the area of analysis in time t. The variable appears in the same 3 core equations as Vacant Developable. It is a very sensitive variable, so care should be used in estimating its value.

   Vacant Undevelopable is a semi-fixed physical variable. It should include flood plains, steep slopes, quarries, and publically owned land that won't be permanently developed. Datum can be obtained from planning agency studies of natural constraints (or physical features) or from U.S. Soil Service county soil surveys. The data may have to be scaled off of maps.

4. Zoned Residential: acres of land zoned for residential use (all types) in the area of analysis in year t. It is a sensitive variable but does not appear in any of the core equations.

   The variable can be estimated from a current (time t') zoning map, or maps if more than one municipality is involved. The datum probably will have to be scaled off from the map(s). The municipality comprehensive plan(s) should be checked to determine if there is more land on the plan designated as residential than currently zoned for. If so, the situation should be discussed with local or regional planners to determine what the probable trend in zoning will be between t' and t.

5. Zoned Office: acres of land in the area of analysis zoned for office, including professional office development in year t. The variable apepars in two core predictive equations, and it is a sensitive variable. It is obtained in the same manner as Zoned Residential.

6. Zoned Industrial: acres of land in the area of analysis zoned for industrial development in year t. It appears in one core equation; it is not a sensitive variable. Again, it is obtained in the same way as Zoned Residential.

7. Onsite Restrictions: a coded variable to indicate what governmental restrictions are expected to be placed on on-lot sewage disposal between the time t and t + 10. This variable is not sensitive nor does it appear in a core equation.

The datum may be available in the 208 Plan (Areawide Wastewater Management Plan). The director of a local or regional sewer authority may hazard a guess as to what the future will bring in the way of on-lot disposal restrictions. Knowledge of past restriction policies may help to ascertain what the future will bring. For example, if the policy is or was that all on-lot disposal is prohibited if housing densities reach 2 per acre, and future densities are expected to be greater, then the variable would be coded as 4.

A problem may arise if more than one policy is expected in an area of analysis. The coding rule that should be used in this and other ambiguous cases is: use the most restrictive category applicable to most of the area of analysis most of the time. Also, severity of restriction has precedence over time but not area. Suppose, for example, that most (>50%) of an area of analysis will not be allowed to have on-lot disposal for six of the 10 years. This is a straightforward case, and Onsite Restrictions is coded 4 (see Table 2-5). If the disposal restriction will only apply for two years on most of the land, the variable is still coded 4 (Restriction Years goes from 6 to 2, however.) Finally, if most of the area will have no restrictions during the ten year period, Onsite Restriction is coded 0 - even if it had more severe restrictions for some of the area of analysis some or all of the time.

8. Restrictions Years: the number of years of time between time t and t + 10 that the coded Onsite Restrictions condition is expected to exist. The variable is not sensitive nor is it in one of the core equations. It is obtained in the same manner as Onsite Restrictions.

9. County Interchanges: the number of limited access interchanges (regardless of functional classification of the roadway) expected in t + 5 in the county containing most of the area of analysis. (If the area of analysis is split evenly among two or more counties, then all counties should be used. Other county level variables must reflect the multi-county situation also, however.)

   County Interchanges is not in a core land use predictive equation. It is not a sensitive variable either.

   Datum for the variable will usually come from the regional planning agency. If the area of analysis is in an urbanized transportation planning area having a so-called 3C planning process, the figure will be available as part of the long-range programming element. If not, the state transportation agency should be consulted. Municipality comprehensive plans, or transportation planning programs, may also be of help in some areas. The City Engineer will be of help in those cases.

10. Limited Access: the number of limited access interchanges (regardless of functional classification of the roadway) expected in t + 5 in the area of analysis.

This variable is not sensitive, but does appear in the Commercial core equation. It is obtained in similar fashion to County Interchanges.

11. Transit Stops: the number of bus and commuter rail transit stops expected in $t + 5$ in the area of analysis. The variable is not sensitive nor does it appear in a core land use equation.

Transit Stops may be obtained from a regional planning agency, or other agency, doing the 3C Plan because a transit element is part of the planning process. Probably, however, the bus or rail company will have to be contacted. This was the way the datum was obtained most often in the case study phase of GEMLUP.

It will be difficult to get an estimate of transit stops for the future. If the transit company or authority does not know what will happen in $t + 5$, use data for the present adjusted by what the recent trend in line closings has been in the area of analysis. If there is no service in the area now, try to find out if any is being seriously discussed. If existing housing densities are low, probably there would not be any service by $t + 5$ even if a transit company is operating in nearby locales.

12. County Growth: the percent change in county population projected for the time period t to $t + 10$. This variable is sensitive but is not used in a core equation.

Datum for the county containing most of the area of analysis is used. If the area is fairly evenly split between two or more counties, all should be used. (If percentage changes are used, a weighted average must be derived. See a standard statistical textboook for information on how to compute a weighted average. The problem can be avoided by adding together the actual population estimates for the two years and computing the percentage change for the total.)

County population estimates are available from many sources. The best might be the regional planning agency, but county planning departments and the state community affairs department are other possibilities. The estimates should be those "officially recognized" for air quality maintenance planning purposes or 208 planning. (If there are differences between these two estimates, take an average.)

Probably decennial or quinquennial projections will have to be manipulated to obtain population estimates for t and $t + 10$. A linear interpolation between years is probably adequate, unless population levels are expected to change dramatically in the counties. In those instances, the projections should be plotted and a smooth curve drawn to connect the point estimates. Year t and $t + 10$ projections can then be read off the curve.

13. Future Population: projected SMSA population for the year t + 10. If the area of analysis is not in a SMSA, use projected county population (see County Growth). The variable is very sensitive, but does not appear in any core equation.

Probably the best source of Future Population is OBERS. The information is also often available from a regional planning agency. If OBERS is used, the data will have to be interpolated to obtain year t + 10 projections (see County Growth).

14. Population Growth: the projected percentage change in SMSA population between t and t + 10. Population Growth is obviously related to Future Population:

$$\text{Population Growth} = \frac{\text{Future Population}_{t+10} - \text{SMSA Population}_t}{\text{SMSA Population}_t}$$

Probably the best place to obtain an estimate for SMSA Population_t is OBERS. Thus both input variables for Population Growth could come from the same place, which has some advantages, such as: fewer sources to locate, fewer assumptions that must be considered, and compatability of inputs and format.

The variable is not sensitive, but does appear in one core equation.

15. Office Vacancy: percent of office space located in the area of analysis that is expected to be vacant in year t. Office Vacancy is in one core land use equation. It is not a sensitive variable.

Obtaining an estimate of relative office vacancy for a future time period will be very difficult, unless there is a sophicated economic planning effort underway in the region. Since this is uncommon, probably the best that can be done is call a local commercial realator, or building manager, and determine what the approximate vacancy rate is now and what the recent trend has been. Because office vacancy is negatively correlated with median income, perhaps a current vacancy rate could be combined with an income proportionality factor to estimate time t office vacancy. However, the effort to do so may not be worth the increase in precision of the variable estimate.

16. Future Houses: the projected number of housing units expected in the SMSA in time t+10. If the area of analysis is not in an SMSA, the projected number of housing units expected in the county in t+10 will be used. (If more than one county is involved, proceed as discussed in 12., County Growth. If more than one SMSA is involved, an unlikely situation, use the SMSA that most of the area of analysis is in.)

Future Houses is not a sensitive variable and does not appear in a core predictive equation.

Datum for the variable may be in a regional or local housing plan. If so, interpolation will most certainly have to be done for the year t+10. The datum could also be obtained by using the OBERS projection of SMSA population and multiplying it by a housing unit per population factor (the reciprocal of average family size). (See also the discussion of family size in 2., Vacant Developable.)

17. Median Price: the projected median price of one acre of vacant, "raw" residential land in the area of analysis in year t. This is a sensitive variable and it appears in two core land use equations, including Residential.

It will be very difficult to get an estimate for Median Price. Possible sources are asking a local developer what the going price of raw land is now and how he thinks it will change by time t. A current land price estimate could be "inflated" by a fixed annual percentage also, if the user can buy the argument that land values go along with (but do not rise faster than or lag behind) the inflation rate. The projected inflation rate itself could come from a general U.S. projection put out by the Treasury Department or other federal government agency.

There is another possible solution. Median Price is not used in isolation in any predictive equation -- it is part of the Land Cost variable, which is Median Price divided by Median Income (see below). If the user wants to make the assumption that these two items vary at the same rate, which is almost identical to assuming that Median Price increases as does inflation, then a current or past Median Price to Median Income ratio could be used for time t also. In that case, the user would first get Median Income estimate for a specific year and then get a Median Price estimate for the same year. The ratio, which was 0.537 on average and varied between 0.058 and 2.546 for the 40 GEMLUP cases, would then be used as Land Cost for time t. If land cost is changing differently than income in the area of analysis, however, this approach should not be used.

18. Future Income: the projected median family income in the SMSA in year t+10. Unrelated individuals are excluded from this definition. The variable is not sensitive and does not appear in a core land use equation.

Future Income estimates may be available from a regional planning agency. It can be obtained from OBERS's per capita income estimate by multiplying the estimate by expected average family size (persons per family). This is the preferred method. Interpolation of data for the correct year (t+10) probably will have to be done.

If the area of analysis is not in an SMSA, then a county-level income estimate must be obtained. This may be available from a regional or State planning agency.

19. Future Employment: projected total employment in the SMSA in t+10. If the area of analysis is not in a SMSA use projected county employment instead. The variable is a very sensitive one; it is used in one core land use equation.

OBERS is a good source of total employment estimates. Interpolation will probably have to be done.

20. Future Medicals: projected SMSA hospital employment in year t+10. The variable does not appear in any core equation and is not particularly sensitive.

Future Medicals should probably be obtained from OBERS estimates of future employment or population. This is done by developing a hospital workers-to-total employment or hospital workers-to-population ratio from the most recent Census data, and applying it to OBERS projections. The second ratio was relatively constant for GEMLUP case studies, and is preferred to the first. Whichever ratio is used, the user must assume that it will not change over time.

21. CBD Distance: the distance in air miles (straight-line) from the approximate centroid of the area of analysis to the approximate centroid of the nearest central business district in a city of 100,000 population or more in year t. This variable is not a sensitive one, nor is it used in a core equation.

The nearest 100,000$^+$ city in time t must first be identified and its CBD located. The distance between centroids is then scaled off of a map with a known scale. A state highway map is generally suitable for this purpose.

22. Airport Distance: the distance in air miles (straight-line) between the approximate centroids of the area of analysis and nearest commercial airport in year t. A commercial airport is an airport with at least one in and one out regularly scheduled flight available to the public on a fee basis. Sight-seeing flights are not included in this definition.

After identifying such an airport for time period t, scale off the distance between centroids on a road map. (Perhaps the regional planning agency should be checked to determine if a new commercial airport will be built before time t that may be closer to the area of analysis than the existing airport.)

The variable is in one core equation (manufacturing), but is not a sensitive quantity.

23. Track: miles of railroad track in the area of analysis in time t. Note that parallel tracks are counted as two tracks. Track is a very sensitive variable and appears in three of the five core land use equations.

Track is easily obtained from USGS maps. A local or regional planning agency should be consulted to determine what changes have occured since the USGS maps were published and what might be expected by the year t. Note that abandoned rail lines that go someplace (i.e., are connected to a mainline somewhere) are counted even if they are not currently used.

24. Area of Analysis: the area of analysis is the legal service area of the wastewater treatment project being studied. It includes the drainage basin for the stream receiving wastes from the project plus other areas connected to the treatment plant by mechanical means. Unit of the variable is acres. Datum will be available in the facility plan provided by the project developer or owner.

The variable appears in all land use predictive equations, both core and secondary. It is a very sensitive variable and must be accurate.

25. Sewered Land: land area in acres within 5,000 linear feet of the major project interceptor sewer(s), if any, in the area of analysis in year t. The 5,000 feet distance is omni-directional, but is only within the area of analysis. The variable is sensitive and appears in one core equation.

The location and extend of all new interceptor sewers will be in the facility plan. If maps provided with the plan are large enough, Sewered Land may be scaled directly from them. If not, the new sewers will have to be plotted onto adequate maps and Sewered Land scaled off of those new maps.

26. Interceptors: running length in miles of the major project interceptor sewer(s), if any, going through relatively undeveloped land in the area of analysis in year t. Relatively undeveloped is defined to be less than one housing unit per acre, and the relatively undeveloped area should be at least 1000 feet deep (i.e., from the interceptor sewer). In other words, if only land adjacent to the pipe is relatively undeveloped and the rest is subdivided and developed, there is no relatively undeveloped land for purposes of computing Interceptors.

Datum is obtained by plotting the interceptor sewer onto aerial photographs or land use maps and scaling off the running length of pipe going through <1 housing unit/acre land. This variable is most easily obtained in conjunction with Sewered Land.

Interceptors is in one core equation, but is not a sensitive variable.

27. Collection Capacity: hydraulic design capacity of an interceptor sewer(s) major project in million gallons per day (MGD) in time t. If the interceptor sewer(s) is(are) phased, the design capacity may be that for the year when the last phase is completed; however, all phasing must occur before t+5. If phasing of interceptor sewers occurs within the area of analysis beyond t+5, the GEMLUP model should not be used.

The datum will be available in the facility plan. The variable is sensitive and it appears in three core equations, including Residential.

If Collection Capacity is not available in the facility plan for some reason, it can be estimated by summing hydraulic flow of the major project interceptor sewer(s), using nomographs of Manning's formula (based on pipe size and slope; see Metcalf and Eddy, Inc. Wastewater Engineering. New York: McGraw Hill Book Company, 1972.). If slope is not known, average values for hydraulic flow based on pipe diameter alone can be used (see Facilities Requirements Branch. Guidelines for 1976 Update of Needs for Municipal Wastewater Facilities. Washington, D.C.: U.S. Environmental Protection Agency, 1976).

28. Peak Flow: anticipated peak flow in the interceptor sewer(s) major project in MGD in year t. If phasing occurs, Peak Flow is for the last phase. Again, all phasing must be complete by t+5.

Peak Flow should be available in the facility plan. If it is not, it can be estimated by scaling known average flow by a population-dependent peaking factor. Such a factor appears as Figure E-2.

The variable is sensitive and it appears in four core equations, including Residential.

29. Treatment Capacity: hydraulic design capacity of the wastewater treatment plant in MGD in year t. This information will be available in the facility plan. The variable is not sensitive nor does it appear in a core equation.

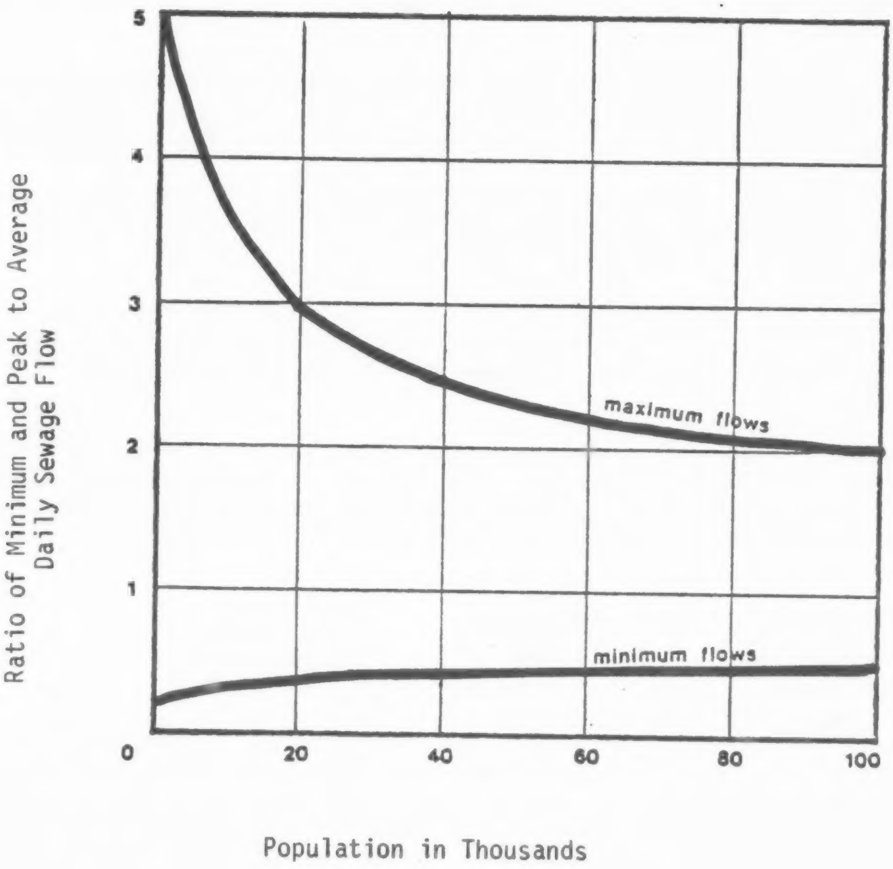
30. Population Served: the population served by the major project facility in year 5. This information will be in the facility plan. The variable is not sensitive. It does not appear in any core land use equation.

31. Project Cost: the total cost of major project construction (in thousands of dollars). This value will be in the facility plan. The variable is not sensitive, and it is not in a core equation.

32. Federal Funds: the federal share of major project cost (in thousands of dollars). This non-sensitive, non-core equation variable will be part of the facility plan.

Figure E-2

RATIO OF MINIMUM AND PEAK FLOWS TO AVERAGE DAILY FLOWS



33. Phasing: a nominal variable that indicates if multi-year construction phasing of interceptor sewers will occur in the area of analysis. This variable will be in the facility plan. It is not sensitive and is not in a core equation.

34. SMSA Area: area of the SMSA in year t in square miles. If the area of analysis is not in a SMSA, county area should be used. Data for the variable is found in the County and City Data Book. A regional planning agency would have the information also.

SMSA Area appears in one core equation, but it is not a particularly sensitive variable.

35. Tract Area: area of the census tracts for which socio-economic data are obtained. Units are in square miles. The data can be obtained by scaling the census tract maps, but it may be available from the regional planning agency also.

If the area of analysis is not tracted, then Tract Area becomes area of the municipality or other civil division used for socio-economic data gathering. Municipality area is found in the County and City Data Book.

Tract Area is a very sensitive variable because of its use in many GEMLUP socio-economic variables (as a divisor). It is in three core equations.

36. Dwelling Units: number of dwelling units in the census tracts in year t, rounded off to the nearest 100 units. (I.e., if the value is 5,327 then 53 is used.) The variable is sensitive and appears in two core land use equations.

Values for the variable for a current or past time period (t') can be obtained from census tract data. The time t' variable can be updated to time t using a population ratio of $\text{population}_t/\text{population}_{t'}$. The number of dwelling units in t would therefore be obtained thusly:

$$\text{Dwelling Units}_t = \text{Dwelling Units}_{t'} \cdot \frac{\text{Population}_t}{\text{Population}_{t'}}$$

Since both t' variables are known, only Population_t is required. A regional or city planning agency would be the source for census tract population projections.

This method assumes that the variable of interest (Dwelling Units) is linearily related to population. If that is not true, then a correction to the ratio has to be made. This can simply be done by applying another ratio to the population ratio to rectify the non-linearity. For example, suppose that average family size has changed radically between t' and t. A family size ratio should then be used along with the population ratio to estimate Dwelling Units.

$$\text{Dwelling Units}_t = \text{Dwelling Units}_{t'} \bullet \frac{\text{Population}_t}{\text{Population}_{t'}} \bullet \frac{\text{Family Size}_{t'}}{\text{Family Size}_t}$$

An example should elucidate both problem and solution. Input data are as follows; DU_t would not be known in practice.

Time	t'	t	Units
DU	100	(150)	Dwelling Units
Family Size	3.00	2.67	People/Dwelling Units
Population	300	400	People

If just the population ratio was used to estimate DU_t, Dwelling Units would be underestimated by about 17 units.

$$DU_t = 100 \cdot \frac{400}{300} = 133$$

Using the correction factor of family size produces the correct answer.

$$DU_t = 100 \cdot \frac{400}{300} \cdot \frac{3.00}{2.67} = 150$$

The principle of using a correction factor to adjust for non-linearity in the dependent variable-to-population relation is used in computing many of the variables that follow.

37. Current Houses: number of dwelling (housing) units in the SMSA in time t: The variable is not sensitive and does not appear in any core equation. Current Houses should be obtained in the same manner as the previous variable. Time t' values would come from the County and City Data Book, while t values would be obtained from regional planning agency projections (its housing element).

38. School Kids: the number of people less than 15 years of age living in the census tracts in year t. The variable is sensitive and appears in one core equation.

The variable is obtained in the same manner as variable 36. Time t variables will have to come from regional or local planning agency projections. The population ratio factor described earlier should be used, supplemented by other ratios of family size or the relative proportion of children in the total population (or both) changes.

For example, if the age structure of the population is changing, a formula for computing school kids might be:

$$\text{School Kids}_t = \text{School Kids}_{t'} \cdot \frac{\text{Population}_t}{\text{Population}_{t'}} \cdot \frac{\text{Relative Proportion of Kids}_t}{\text{Relative Proportion of Kids}_{t'}}$$

Using the same numerical example used in 36 above, say the proportion of school aged children (0-14) in the total population changed from 0.367 in t' to 0.263 in t. This means that the population is aging. Multiplying these proportions by total population results in 110 Schools Kids in t' and 105 in t. Plugging numbers into the formula gives the correct answer.

$$\text{School Kids}_t = 110 \cdot \frac{400}{300} \cdot \frac{0.263}{0.367} = 105 \text{ children}$$

The alert reader may question why the time period indices of the correction factors are different in 36 and 38. In 36 the time t' correction factor is in the numerator, while in 38 it is in the denominator. The reason is that time indices must cancel as well as variable units. In 36, the Family Size factor has units of:

$$\frac{\text{Population}_{t'}}{\text{Dwelling Unit}_{t'}} \cdot \frac{\text{Dwelling Unit}_t}{\text{Population}_t}$$

(The numerator is multiplied by the reciprocal of its denominator.) The units now cancel throughout the original equation.

In 38, Relative Proportion of Kids has units of:

$$\frac{\text{School Kids}_t}{\text{Population}_t} \cdot \frac{\text{Population}_{t'}}{\text{School Kids}_{t'}}$$

These units also now cancel with the original equation.

39. Vacant Houses: the percentage of vacant available dwelling (housing) units in the census tracts in time t. The percentage is coded as a decimal; i.e., 10% is coded as 0.1 and 17.3% is coded as 0.173. Datum for time t' would come from census tract information. This could be used for time t, or an appropriate planning agency could be contacted for a more recent estimate. While the variable does not appear in a core equation, it is a very sensitive variable in those equations where it does appear.

40. Nonmobility: the percentage of families in time t living in the same house as they did in t-5. The geographical area is the census tracts, and the datum comes from Census of Population and Housing: Census Tract books. The variable appears in the residential core equation and is sensitive. Percentages are coded as decimal equivalents.

The most recent census value could be used as a surrogate for Nonmobility. If a comprehensive housing element planning effort exists in the region, the variable could probably be estimated from it. The variable will most likely fall between 45 and 65 percent and is thought to be relatively constant in the short run.

41. Median Income: the median income of families living in the county or counties containing most of the area of analysis. The time index is year t.

A time t' value can be obtained from the County and City Data Book. A more recent estimate will probably be available from a socio-economic profile done by the regional planning agency.

Median Income is only used in conjunction with Median Price (17). See the discussion of that variable for more information. Median Income is sensitive and appears in the residential and one other core land use equation.

42. Current Income: the median family income of people living in the SMSA containing most of the area of analysis (in time t). If the area is not located in a SMSA, county data are used, which means that Median Income = Current Income. The variable is not sensitive nor does it appear in a core equation; in fact, it is only used in disaggregating residential predictions into the single- and multiple-family categories.

If the area of analysis is in a SMSA, then time t data can come from OBERS by multiplying the per capita income estimate by average family size. Because OBERS data are in terms of some specified base year dollars, Current Income should be updated to account for inflation.

Another source of information can be a regional planning agency socio-economic profile.

43. Poverty: the percentage of total families in the census tracts with income below the H. E. W. poverty level in time t. The percentage is coded as a decimal. The variable is not sensitive and is not used in a core equation.

Time t' values can be gotten from census tract data. Because the variable does not change rapidly, the time t' figure should be adequate for predictive purposes. If a more recent estimate is desired, then a socio-economic profile done by a public planning agency should be consulted.

44. Index One: the Consumer Price Index (CPI) for year t. The Index is published for selected major cities in CPI-Detailed Report (Bureau of Labor Statistics, U. S. Department of Labor). Use the value for the nearest major city.

The variable is only used in combination with Index Two. An estimate for time t if it is in the future will not be available. The recommended way to proceed is to use the current CPI for whichever Index (One or Two) applies to the later year and go backward in time for the other index. There is no need to update the two indices with an inflation rate, because each index would be changed by the same percentage and the net result would be the original difference.

The variable is not sensitive and is not used in any core land use equation.

45. Index Two: the CPI for the year of federal funding· the year should be less than time t. The variable is not sensitive nor is it in a core equation. It should be obtained in the manner in 44, above.

46. Government: the total amount of county government expenditures in millions of dollars in year t. (Round off $7,761,000 to 7.76, for instance). Use the county or counties containing most of the area of analysis. The variable appears in one core land use equation; it is not sensitive.

It will be hard to obtain data for this variable unless the county projects expenditures in advance. Perhaps the regional planning agency might be doing fiscal analyses of future expenditures. Probably the only way to get an estimate is to obtain recent county expenditure audits, determine what the yearly trend is by plotting values on a graph, and project ahead using the same rate-of-change. This trend analysis will only be approximately valid, but the estimate should be accurate enough for the use to which it is put.

47. Current Employment: total SMSA employment in year t. If the area of analysis is not in a SMSA, use county employment data. The variable appears in one core equation, but is not sensitive.

SMSA total employment projections are available in OBERS. Some interperlation between OBERS projection years will have to be done, however. If the area is not in a SMSA, perhaps the information can come from a county-level socio-economic profile maintained by a county or regional planning agency (such information will be available in a 3C transportation plan, for instance). If not, use past census estimates projected ahead by a percentage change number used by state or regional economic/industrial development organizations.

48. Unemployment: the percentage of unemployed workers in the census tracts in year t. (Percentage is coded as a decimal). This variable is sensitive, but does not appear in a core equation.

An estimate for Unemployment might be contained in a socio-economic profile done by a county or regional planning agency. Since it is a relative variable, the current value could be used by assuming no change. A proportion could also be established between unemployment percentages for the area of analysis and some (larger) municipality for which a time t estimate is available. For example, say the census tracts containing most of the area of analyses has an unemployment rate of 6% in 1980, the latest census year. The county's unemployment rate was 10% in 1980. Year t is 1984, and the state has projected an unemployment rate of 8% for the county in 1984. An estimate of Unemployment_t then is:

$$\text{Unemployment}_t = \text{Unemployment}_{1980} \cdot \frac{\text{County Unemployment}_t}{\text{County Unemployment}_{1980}}$$

$$= (0.06) \cdot \frac{0.08}{0.10} = 0.048$$

$$\text{Unemployment}_t \cong 0.05$$

49. Office Employment: the number of employed office workers in the census tracts in time t. The variable is sensitive, but is not in a core equation.

    Values for time t will be difficult to come by. Office Employment should be obtained for a current or recent time period t' and adjusted by a population ratio (see 36).

50. Manufacturing Workers: the number of manufacturing workers living in the census tracts in time t. This variable appears in two core equations, including residential. It is also a sensitive variable. Probably the easiest way to obtain a value for this variable is to get the most recent U. S. Census estimate and apply a population ratio to it (see 36).

51. Current Medicals: the number of hospital workers living in the SMSA--if there is one--in year t. If the area is not in a SMSA, use county figures. Time t' values come from the U. S. Census, and a projection to time t can be made using a population ratio procedure. See item 36. The variable is not sensitive nor is it in a core equation.

52. Drivers: the number of people living in the county who drive to work, either as a driver or a passenger, in year t. The value should be rounded and coded to the nearest one hundred people; i.e., 1,371 is coded as 14. The variable appears in the residential core equation; it is not sensitive.

Drivers may be available in a regional 3C plan. Probably a population ratio will have to be used to update U.S. Census information. Exactness is not required, as evidenced by rounding off of the datum.

III. Sensitivity Analysis

The impact that a variable has on a particular equation depends upon its contribution to total variance explained in the dependent variable by the equation. I call this impact "sensitivity." A sensitivity analysis was performed for all predictive equations.* The analysis took the form of answering the question: "What is the percentage change in the dependent variable when all other independent variables are set to their mean value?" The higher the resultant change, the greater a particular variable's impact is on the resultant, and the greater is its sensitivity. There are other ways to do sensitivity analyses, and one alternative method is used for the Residential equation for illustrative purposes.

The user should be careful to obtain good data for sensitive variables because of their importance. Assuming that carefulness is related to time spent in obtaining data and that user time is a scarce resource, a user should spend most of his constrained time on important variables and relatively less on the others.

Note that this sensitivity analysis has nothing to do with model validation, which is discussed in Section II.B of the Report. In particular, this sensitivity analysis should not be confused with coefficient stability analysis described in that section, which it superficially resembles.

Results of the sensitivity analyses follow. If the percentage change value has a negative sign, it means that a positive change in the independent variable causes a negative change in the dependent variable (an inverse relationship, in other words).

Residential Equation

The Residential equation is most sensitive to changes in Nonmobility, and is fairly sensitive to all other variables except Driver Density. The percent change in Residential (in terms of housing units per acre) due to a 10.0% increase in each independent variable, with all other independent variables held constant at their mean value, is:

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*In English units only; results of the analysis in metric units would probably be different.

Nonmobility	-9.7
Vacant Land	-6.1
% Collection Reserve	3.3
Land Cost	3.3
Manufacturing Density	2.6
Driver Density	1.0

Another way to look at variable sensitivity is to set the variable at its extremes (low, usually zero, and high, the maximum value recorded during GEMLUP field data gathering effort) and see what happens to the dependent variable. This was done for the Residential equation; results are presented in Table E-5.

Office-Professional

The Office-Professional equation is most sensitive to changes in Office Zoning, which may be a surprise to jaundiced observers of the local zoning process in this Country. No other variable has nearly as important an impact on Office-Professional as does Zoning. The next most important variable, Railroads (or the density of railroad track in the area of analysis), is odd. Its importance is undoubtedly due to its being correlated to a factor that is also highly correlated with office space, perhaps size or age of city (themselves highly correlated), a high order of central place functions, or industrialization.

The percentage change in Office-Professional due to a 10.0% increase in each independent variable, with all other independent variables held constant at their mean value, is:

Office Zoning	7.9
Railroads	2.1
House Density	1.5
Peak Flow	1.4
Population Growth	0.8
Industrial Zoning	-0.7

Table E-5

PERCENTAGE CHANGE IN RESIDENTIAL DUE TO EACH INDEPENDENT VARIABLE SET TO ITS EXTREME VALUES & ALL OTHER INDEPENDENT VARIABLES SET AT THEIR MEAN VALUE

Independent Variable	Range of Dependent Variable (%)	Difference in the Range (%)
Land Cost	33.0 - 233.5	200.5
% Collection Reserve	65.8 - 201.1	135.3
Nonmobility	63.3 - 197.1	133.8
Vacant Land	63.8 - 160.5	96.7
Manufacturing Density	73.6 - 157.9	73.6
Driver Density	90.4 - 161.4	71.0

As can be seen by comparing data in the text with Table E-5, a variable's rank order with respect to sensitivity varies from one method to another. The reason for this is that the relationship between mean and extreme values varies greatly among independent variables. Variables widely scattered around their mean or having a skewed distribution will have a potentially large impact on the dependent variable if they are misspecified.

Recreation

Recreation, in units of acres of land per area of analysis, is most sensitive to Vacant Houses (negative relation) and the ubiquitous Railroads. The percentage change in Recreation because of a 10.0% increase in each independent variable, with all other variables held constant at their mean value, is:

Railroads	6.1
Vacant Houses	-6.1
Office Density	4.6
County Growth	4.0
Industrial Zoning	-1.7
Treatment Capacity	1.3

Manufacturing

Manufacturing, in units of floor area per area of analysis, is most sensitive to Office Zoning and Vacant Land. The second relation is logical but the first is not. Apparently there is a factor that affects both industrial and office land uses (but not industrial zoning). This factor could probably be identified by analyzing causal relations found in Volume I of GEMLUP (EPA-450/3-78-014a), but this has not been done because of time constraints.

The percentage change in Manufacturing due to a 10.0% increase in each independent variable with all other independent variables held constant at their mean value is:

Office Zoning	7.0
Vacant Land	-5.2
Railroads	2.7
Office Vacancy	1.6
Manufacturing Density	1.3
Airport Distance	1.2

Wholesale

Wholesale land use, in terms of floor area per area of analysis is most sensitive to Employee Ratio and Income. Of all the independent variables investigated so far, they are the only ones that produce a greater than one-to-one relative change in a dependent variable. Compared with preceeding equations, Wholesale is relatively sensitive to all its independent variables, but Employee Ratio and Income will have a much greater impact than any of the others.

The percentage change in Wholesale due to a 10.0% positive change in each independent variable, with all other variables held constant at their mean value, is:

Employee Ratio	47.6
Income	-21.7
Unemployment	7.1
Driver Density	6.0
Office Vacancy	5.7
Office Workers	5.3

Highways

Highways, in units of non-expressway lane miles per area of analysis, is the most sensitive to Railroads, which has to be a surrogate for some other variable. The percentage change in Highways because of a 10.0% increase in each independent variable, with all other variables held constant at their mean value, is:

Railroads	3.9
Land Cost	2.9
Government	-2.0
Collection Reserve	1.3
Interchange Density	1.1

Education

Education, in terms of floor area per area of analysis, is most sensitive to Sewer Service. The percentage change in Education due to a 10.0% increase in each independent variable, with all other variables held constant, is:

Sewer Service	3.7
Land Cost	2.0
On-site Restrictions	2.0
County Growth	-0.9
Sewer Costs	-0.5
Poverty	*

* Less than a -0.05% change.

Commercial Equation

The Commercial equation is equally sensitive to changes in Kid Density, Vacant Land, and Sewer Service. The percentage increase in Commercial (in terms of floor area per area of analysis) due to a 10.0% change in each independent variable, with all other variables held constant (at their mean value) is:

Kid Density	-3.9
Vacant Land	-3.7
Sewer Service	3.6
Employment Growth	-0.9
Interchanges	0.8
% Collection Reserve	-0.6

Other

Other land uses include transient lodgings (hotels, motels, and rooming houses), churches and other religious structures, cultural activities (museums, theaters, auditoria, and libraries), and indoor recreational facilities (separate from schools). Other does not include hospitals, prisons, or colleges. The units of Other are in square feet of floor area per area of analysis. The percentage change in Other because of a 10.0% increase in each independent variable, with all other variables held constant, is:

Income	-116.2
Vacant Houses	- 18.2
Railroads	13.9
County Growth	6.6
Residential Zoning	5.4
Interchange Density	-2.1

The highly sensitive negative relationship between Income and Other is puzzling at first glance because, it is commonly said, cultural activities are directly related to the income and educational level of residents. An explanation for the inverse relation can be obtained from the zero-order correlation coefficient. Other is significantly positively correlated with population density, which implies that cultural activities are most often found in highly developed areas. This is certainly true of many museums and auditoria, although theaters are more evenly dispersed throughout a metropolitan area (espcially movie theaters). Motels and hotels are also found downtown, particularly in large cities. Next, there is a negative, significant correlation between population density and per capita SMSA income, which Income measures. These two factors taken together would result in the negative relationship between Income and Other that is observed above.

Summary

The preceding analyses of sensitivity were used in developing a list of very sensitive and sensitive variables. Variables not on the list were labeled insensitive or not sensitive variables. The designations correspond to those used in Section III of this Appendix.

Postscript

Peter Guldberg, principal author of the main report reviewed this Appendix and made an important point regarding this section. He says that really nothing can be said about causal relations in predictive equations because individual regression coefficients are biased due to interaction among the independent variables. This can be seen by changing the order that variables enter a regression equation; variable coefficients change as their order of entry changes. Thus, comments concerning the relative causal effect of a variable vis-a-vis others cannot be made.

I make these types of comments in Office-Professional when discussing the Office Zoning variable and in Other when describing the Income variable. Please disregard any implications of causality in these discussions. What I say about relative sensitivity (as defined here) of the variables and the pragmatic reasons for their relative sensitivity still hold, however, but only within the abstract context of the regression equation itself. See Volume I for an extended discussion of "real-world" causal implications of GEMLUP equations.

IV. Distribution of Predicted Land Uses Within the Area of Analysis

The quantities of land uses predicted to occur within ten years of increased sewage capacity apply to the area of analysis as a whole. There is no spatial resolution to the predictions, in other words. Nor was any ever intended.

Spatial disaggregation was not attempted for three reasons: (1) it would have complicated the modeling exercise immensely, (2) it would have ignored local knowledge of an area, and (3) it was unnecessary from an air pollution emissions estimation viewpoint.

Our desire to provide relatively simple, easy-to-use predictive equations would have been obviated if disaggregated predictions were made. Doing this would require that some sort of internal grid system be used, that land uses by grid cell be obtained, and that cell-specific predictive equations be generated. The user would then have to grid off his area of analysis and use nine predictive equations for each cell. The user would also have to allocate existing land uses to each cell to ascertain what new development was predicted to occur within a particular cell.

We wanted not only to avoid doing cell-by-cell analysis but to use local knowledge of existing and proposed development. Local and regional planners know where things are and where and what kind of development is about to go in next. They also know what the zoning is and where streets and highways will be constructed or improved. It was felt that this local knowledge would be more accurate in internally allocating development than using a numerical technique based on case study information. Not only that, but if all development followed a deterministic pattern there would not be a need for planning at all. Phrased another way, the community--represented by its planning agency--should be able to decide where development should go given the fact that development is coming. Zoning is obviously based on that premise, and we wanted to work within that framework.

Finally, for most air quality impact analyses, it is immaterial where development is within a region as only total regional emissions are used in the impact assessment. This is particularly true for most land use types, whose individual emissions are so low that they are lumped together as "area source" emissions anyway. In other words, air pollution modelers do not need individual source emission estimates for their diffusion work for most land uses in a community. They only require specific estimates for large "stationary sources" emitting approximately 100 tons or more of pollution per year; these sources are large ("heavy") industrial firms, power plants, refineries, and some extractive manufacturers. And it should be noted that specific estimates may not even be required for these large sources for all pollutants. Hydrocarbon emissions, for instance, are usually only needed for an urbanized area on SMSA, because the analytical methods used to convert hydrocarbon emissions into ambient ozone concentrations are aspatial. In fact, the air quality analyses are usually done on a multi-county area larger than an SMSA (called an AQCR, or Air Quality Control Region).

Distribution of predicted land uses within the area of analysis, then, is done by the user using personal knowledge of the area, data in the comprehensive plan, the zoning map, and information on development trends obtained from personal contacts, subdivision proposals and building permits. It is intuitive to some extent, obviously, but should be suitable for most projection purposes. If disaggregated land use predictions are required for some reason, the user will have to use another methodology; GEMLUP cannot help.

V. Disaggregating Residential and Commercial Predictions

Worksheet 4 contains formula to disaggregate residential and commercial land use predictions. (Worksheet 3 contains row entries for them, but data for the rows come from Worksheet 4.) As explained in Section I.A.2.b., the disaggregation equations were developed using logit analysis, where percentage breakdowns of the classes of residential and commercial land uses were fitted to a logistic S-shaped curve. The equations were transformed into regression equations for the user.

The disaggregation equations require that the following variables be defined. (If a variable is derived from input variables--those a user must obtain data for--the input variables are shown in parentheses.)

Residential Disaggregation Equation

Kid Density (school kids, dwelling units)
Income Growth (future income, current income)
Sewer Service (Sewered land, area of analysis)
Office Zoning (zoned office, area of analysis)
Nonmobility
Hospital Growth (future medicals, current medicals)
Housing Growth (future houses, current houses)
Poverty
Railroads (track, area of analysis)
Peak Flow

Commercial Disaggregation Equation

Office Vacancy
Onsite Restrictions
Treatment Capacity
Kid Density (school kids, dwelling units)
Restriction Years
Phasing
Transit Stops
CBD Distance
Government
Vacant Land (vacant developable, area of analysis)

Of the 24 different input variables needed to use the disaggregation equations, 11 are used in core equations and only 4 are used in the residential equation. Consequently, if a user opts for the simplified approach discussed in Section I of this Appendix, he or she would not be able to disaggregate residential and commercial predictions without getting more information. This defeats the intent of simplification.

How the user gets around this problem should depend upon what he or she does with the predictions. For instance, if the user is primarily interested in using GEMLUP results to estimate area emissions, the commercial disaggregation need not be done since the per floor area emission rate is the same for all commercial categories. A residential disaggregation should be done in this case, however, because per unit area emission rates do vary for residential categories for some, but not all, pollutants.

Two logical ways to disaggregate commercial and residential predictions are (1) use the existing local breakdown for the future estimates, or (2) use the breakdown found in the GEMLUP case studies. The existing local breakdown for the residential categories can be obtained from U.S. Census information. The existing local breakdown for commercial land uses may be available from a local or regional planning agency, but probably will not be. In that case, the only option is to use GEMLUP case study information.

The residential and commercial breakdowns found in the GEMLUP cases appear in Table E-6. They could be entered directly onto Worksheet 3 (as decimal equivalents) and multiplied by the predicted quantities on the left to come up with estimates of disaggregated land use. Again, local knowledge should be used to determine if the GEMLUP breakdowns are reasonably consistent with the existing development pattern of the area being investigated. The case studies obviously had a lot of single family detached housing and small (usually strip commercial and neighborhood shopping center) commercial development. If the user's area of analysis has a greatly different development pattern, the disaggregated equations should be used instead of case study breakdown.

Table E-6

RESIDENTIAL AND COMMERCIAL BREAKDOWN FOR GEMLUP CASE STUDIES

Disaggregated Category	Mean Value (Percent)	Range of Values (Percent)
Residential	100.0	
Single Family	83.2	33.7 - 95.1
Two-Family	4.8	0.0 - 27.0
Multi-Family	12.0	0.0 - 39.3
Commercial	100.0	
Large	10.7	0.0 - 54.5
Medium	10.5	0.0 - 49.2
Small	78.8	29.6 -100.0